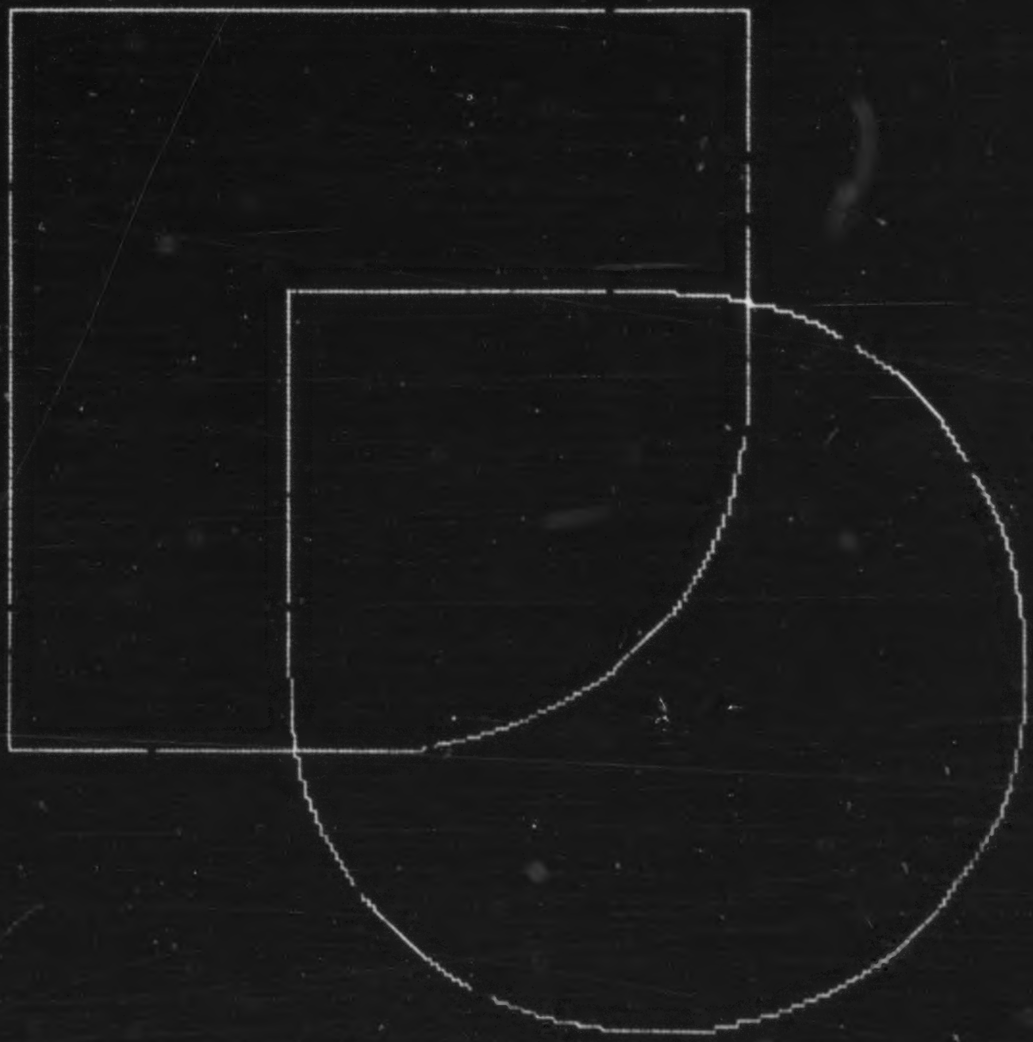
TELIDON

TELIDON BEHAVIOURAL RESEARCH 1

Ottawa February 1980



Behavioural Research on

TELIDON I

Behavioural Research Group

Department of Communications

1980

TELIDON BEHAVIOURAL RESEARCH I
DEPARTMENT OF COMMUNICATIONS
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Preface

Telidon, the Videotex system developed in Canada, is now being prepared for field trials in Canadian homes. Many design decisions are being made during this preparation phase, some of which will affect users. The Behavioural Research Group at the Department of Communications has considered many of these decisions and has conducted some studies both to outline which of the decisions will affect users and to help make recommendations for designers. This set of reports outlines the results of this work to date. It is the first to be prepared in this format and is intended for communication with those who are also involved in the preparation of Telidon trials.

The reports presented here fall into three categories: reviews of the human factors issues arising from Telidon technology; studies of visual display characteristics that are optimal for users; studies of data base characteristics optimal for users.

1. Review of Human Factors Issues.

"Telidon, the Canadian Videotex System and its Implications for Information Science" presents an initial set of questions regarding information creation on Telidon with a review of the technical capabilities and limits of Telidon.

"Telidon Videotex and User-Related Issues" reviews the user related issues of visual display and the interaction protocol for information retrieval.

"The Implications of Telidon for Information Science" presents a general model by which to understand Telidon research and provides a review and update of problems of data bank planning and organization.

2. Human Factors of Visual Displays.

Four reports present experimental work conducted at the Communications Research Centre. "Character Sets for Videotex Field Trial Terminals" summarizes the experimental and demonstration studies and recommends optimal character spacings based on both readability and economic considerations.

The following two papers, "Spacing of Characters on a Television Display: 5 x 7 character set and 7 x 9 character set" present the results of empirical studies on the legibility of characters when various spacings are used. These reports conclude with recommendations for spacing of each character set on Telidon visual display.

"Placement of Accents on Characters" presents a study of different techniques of placing accents on French language characters. Recommendation about which is most acceptable to users is based on preference data collected from Francophones.

3. Human Factors of Data Bases.

Two papers: "The Optimum Number of Alternatives to Display on an Index Page in an Interactive Telidon Data Base" and "Broadcast Telidon: The Optimum Number of Alternatives per Index Page" present a model of how the Telidon data base should be designed so that users reach the information they seek as quickly as possible. Taking several variables into account, the model recommends that the number of alternatives on an index page, for interactive Telidon (in particular, see the summary section of each article). should be from 4-8. For Broadcast Telidon, either full channel transmission or vertical blanking interval transmission), about 10 alternatives on a page is close to optimal. Other recommendations are discussed in these two articles (in particular, see the summary section of each article).

"Evaluation of Tree Structured Organization of Information on Telidon" is directed towards assessing how difficult it is for people to find information in the data base. In general, it is a first attempt at developing a methodology for evaluating and improving tree-structured data bases.

Some of these reports have been published as noted on the papers. Any comments or questions about this research program should be addressed to the author:
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CHAPTER I

REVIEW OF HUMAN FACTORS ISSUES INVOLVED IN TELIDON

TELIDON, THE CANADIAN VIDEOTEX SYSTEM, AND ITS IMPLICATIONS FOR INFORMATION SCIENCE

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ABSTRACT

Telidon is the name of the Canadian Videotex System, a public-accessed interactive information retrieval service now being developed in Ottawa. Several other Videotex and teletext (broadcast) developments are taking place internationally with graphic and alphanumeric information available to homes and businesses on visual displays (TV sets). Technical characteristics of Telidon for visual display and search structure influence the presentation of information on Telidon. Questions remain about the information content that can best be provided on Telidon, about indexing or classification schemes and about how the user will pay for information. The Information Science Community could make a contribution to these questions.

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INFORMATION IMPLICATIONS OF TELIDON

INTRODUCTION

Members of the information science community will be aware that technological developments are creating an "information revolution". New technology in the computer and telecommunications fields are coming together to bring about a profound change in the way we access and store information in our society. Within a few years we can look forward to having access in our homes to computer stored data bases by using telephone and TV equipment. We will be able to interact with the data base to look up the latest hockey scores or stock market prices, and to shop for a house by looking at plans and pictures, find out how to adopt a baby or where to go for counselling. These are the information retrieval activities now in the process of development. Later, the same equipment will serve a messaging function. We will be able to send letters to friends, make theatre or airline reservations, order and pay for groceries and perhaps even be interviewed by the computer about our medical complaints before going to the doctor.

Telidon is one of the technological developments which are destined to have a major impact on our lives in the near future. Telidon is the name given to the Canadian Videotex system and Videotex is a term adopted internationally as a temporary generic term for public-accessed interactive information retrieval services. Telidon was developed at the Communications Research Centre in Ottawa.

This paper describes some of the characteristics of Telidon and places it in the context of other developments internationally in this field. It then poses a challenge to the information science community to be influential in the development of information to be provided on Telidon.

VIDEOTEX AND TELETEXT

Before describing Telidon in detail, it is useful to distinguish two-way videotex services from one-way teletext services. Videotex systems allow the user to access computer stored information using a key pad or more complex key board, a modified TV set or other electronical visual display, and a telephone or other transmission line. In contrast, one-way teletext services are broadcast and the user with a decoder and TV set may "grab" a frame as it goes by in the broadcast signal and display it on his TV screen. Access time for teletext depends on how long it takes for the page to go by and could be up to a minute or longer depending on the size of the data base.

Both videotex and teletext systems display alphanumerics and graphics with colors. From the users point of view, videotex systems can offer access to much larger data bases and will have a more rapid response time on the average.

Teletext services are now being offered in Britain by the BBC (Ceefax) and the Independent Television companies (Oracle).

The broadcasting authorities for Ceefax and Oracle provide the editorial or information gathering services as well as broadcast channel, a major difference from Videotex systems where information and carrier services are provided by different groups so far. (Pye, 1978)

Videotex Developments Internationally

In addition to the Canadian development, Telidon, there are similar developments in two-way information retrieval internationally. The British Post Office developed Prestel (originally called Viewdata) and is currently undergoing a market trial planned to a total of 1600 users. Public service is due to start in the spring of 1979. They hope to have 250,000 pages of information available by that time with almost 200 independent companies providing the information.

The French Titan system, a telephone videotex service, uses a display system called Antiope developed in French laboratories. Still largely at the laboratory experimental stage, field trials of Titan are planned for 1980.

In Europe, the West German and the Dutch telephone authorities have purchased Prestel technology and other countries are showing an interest. Several companies in the U.S. are also interested in Prestel technology. Japan has been developing several videotex and teletext experiments with their own technology.

The Canadian Videotex system, Telidon, is sparking interest internationally as field trials are planned. As of mid-february, 1979, Bell Canada, in cooperation with Torstar and Southam Press has launched a field trial of their videotex system known as 'Vista' which will include experiments with Telidon. Other trials are being planned, in cooperation with the Department of Communications, by the Manitoba Telephone System, Alberta Government Telephones, the Ontario Educational Communications Authority, Telecable Videotron in Montreal, and Grand River Cable who plan to launch a teletext trial.

TECHNICAL ASPECTS OF PROVIDING INFORMATION ON TELIDON

Visual Display Characteristics

The storage and communication of characters and graphics on Telidon, which is different from the British and French systems, influences the process of creating and displaying pages of information. The European systems, both British and French, transmit images in mosaic picture elements. A visual frame consists of 24 rows of 40 characters in the British 625-line TV format and 25 rows of 40 characters in the French system. Graphic images are made up of block graphic characters which become elements in a mosaic. In contrast, Telidon was developed using a set of Picture Description Instructions (PDI's) which describe the picture in terms of basic geometric elements: point, line, circule, rectangle, polygon, arc, bit by bit facsimile-like pictures, and text. This concept permits the growth of large information data bases which would not have to change to accommodate improvements in terminals or new communications media. (Bown et al. 1978)

INFORMATION IMPLICATIONS OF TELIDON

Text on Telidon is, at present, limited by the North American 525 line TV standard to 20 rows of 40 characters but better resolution visual displays will make this limit unnecessary. Colors for the Telidon display are limited at present to 8, including black and white, with 6 grey levels in addition. Many more colors are possible as the technology develops.

Tree-structured Data Base

Access to information data bases, at present, restricted to tree-structure search techniques. Tree-structures have been developed first for Telidon, as for Prestel, because they are most economical of computer processing time. Telidon services are expected to be used by many more people simultaneously than even the most popular present data base, thus economy of computer resources is important to keep response time to a reasonable level.

The Telidon tree-structure has a general index page, page 0, followed by 9 more levels of pages. At each level there are 9 choices. There is also the possibility of a 1000-page sequential file at any point on the branch of a tree. The total capacity exceeds 10^{11} addressing possibilities, obviously an enormous quantity. Since the British, after more than a year, are just working up to 2 x 10^5 pages, we need not feel limited by space. There is also no reason for only one data base to exist.

Each page in the tree has a single address and can be reached in two ways, through the branches of the tree that lead to it, or by addressing it directly. An alphabetic index on a page of the tree-structure can be used to give page addresses. It is also possible to return to page 0 from any page and proceed again through the tree and to move backwards and forwards one or more pages at a time throughout the data base.

The Telidon technology provides potential for graphics and text display which will be limited mainly by the imagination of the page designer. The tree structure also provides facility for a very large data base but limits the search procedure, at present, to choice of one out of 9 options at each level.

QUESTIONS ABOUT INFORMATION PROVIDING

The capabilities and limitations imposed by the Telidon technology for the visual display and the access to information pose some questions which the information science community may help to answer. In fact, I wish to present them as a challenge to Canadian information scientists to provide the necessary technical developments and the rational basis for judgements that will affect how Telidon is presented to us in our homes.

INFORMATION IMPLICATIONS OF TELIDON

You might consider the issues at two levels: "What can be done with the technology as it stands today?" and from the user's point of view, how should we rank order the technical developments that remain to be completed? Which will be most important for the user?"

The issues for your consideration then are these:

1. What information will best be presented with Telidon technology?
2. What indexing system or systems should be used for the umbrella or routing pages of the tree-structure and can they be standardized?"
3. How should users pay for information received on Telidon?

Information Content

Information for Telidon services to businesses and homes will be provided by organizations or individuals called Information Providers (IPs). For Prestel, the British Post Office has taken the role of providing the channel for communication but not the content. IPs range from small to large companies and can be allocated up to 10,000 pages in the data base.

In Canada, the carriers of communications will not be the government but it is not yet clear whether telephone or cable companies or both will be carriers. Nor is it clear who will take the role of IPs. One of the major issues of the next few years will be what information to present on Telidon. What will the user want to have access to on his Telidon screen? What kind of information would make the best use of graphics capability and the facility for having access instantly to rapidly changing information? What information will the user be willing to pay for? Should some information that he won't pay for be provided anyway? Will it replace or augment the newspaper and other publications? The only empirical information presently available comes from Britian where a magazine called the Prestel User's Guide is now being published. Far from replacing publishing, Prestel has stimulated another publication. Information provided on Prestel is a great variety: news, train schedules, information about restaurants, travel, theatre, insurance and many others.

There are no data available yet from the British market trials about what information is best liked by British users. When it becomes available, it will be perused with a great care, however, the desires of the Canadian public for information are not necessarily the same as those of the British, and the Telidon system with its technical differences may allow for different information.

I think the information science community, with its experience in providing for the information needs and desires of the public in libraries, could make a contribution to the information content of Telidon. The publishing industry has already shown an interest. The press (the Globe & Mail, Southam, Torstar, La Presse) are actively pursuing an interest in Telidon trials. Education groups are becoming interested. There are many more private and publically supported information creators who could contribute to Telidon content.

Indexing of Information

A second set of questions arises from the tree-structured search available on Telidon at present. Given its limits, how should information be indexed for easy access by users? If a variety of information data bases for Telidon are developed across the country, as seems likely, it would appear reasonable to have standard indexes so that a traveller may find what he is looking for in various parts of the country. Is it possible to develop an index or a set of indexes that would serve as a standard? Should there be such standards activity in progress now?

Indexing of information can become especially important if it serves as a filtering device for a user. By selecting certain branches of a tree, the Telidon user may be exposed only to certain information, a very different process from browsing through a magazine. Will people be inclined to such filtering as they approach information overload? (Science Council of Canada, October 1978) Can indexing or cross-reference systems be designed to avoid the potential negative effects of user selection? To my knowledge, none of the indexing questions has been addressed yet.

Looking farther to the future, if the technology were to develop so that we were no longer limited to the tree-structure, what search structures would best suit users? What information would users have access to with different structures and how important would that be for them?

Another set of future questions concerns query languages and their acceptability by the general public. User interaction with a tree-structured data base is very simple, requiring only a multiple-choice decision and the push of a few keys on a keypad. If more complex interaction is developed with full keyboards in every home, what query languages will be most suitable for the general public?

User Payment for Telidon Information

Information is not free. Even the information in the public library is paid for by our taxes. Nevertheless, there is a value in our society that information be available to individuals regardless of their ability to pay. Of course, that isn't all information, but at least most of the important archival information of our society is publically available. How, then, should a user pay for Telidon information?

In Britain, Prestel began with a pay-by the page system, however, that was recently modified so users do not pay for index pages but only for final pages containing the information sought. There is an additional time-on charge which is less after 6 p.m.

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For Telidon, if the index pages are free, then should payment be by the page only or by the minute or some other scheme?

A related question has been posed by the Science Council of Canada (December, 1978) "Is information a commodity or is information a right?". If we pay by the page or minute, we treat information as a commodity? Perhaps that will also influence the type of information that we deem suitable for Telidon. If we pay with taxes and make the information free to the individual, we treat information as a right and uphold our value of free access to information by all the citizens. However, we may at the same time undermine a major sector of our economy, the information providers, who market information to individuals for profit.

None of these questions has been solved. Some require technical development; indexing schemes and perhaps natural language query modes can be developed. Some require reasoned analysis based on our previous experience with other media and market research; the kind of information that should be presented on Telidon can be guessed at and our concepts refined with market analysis and trials. Some require debate as well as reasoned analysis of the options; how the user should pay for Telidon information may be answered by debate or it may be left to the market place to decide. These are issues that will affect the quality of information to which we have access through Telidon in the near future.

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Telidon Videotex and User-related Issues

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Communications Research Centre

This paper was presented at the Conference on Processing of Visible Language at Niagara-on-the-Lake on 4 September 1979, and will appear in the Conference Proceedings.

Abstract

Videotex systems are interactive visual communication systems intended intially to permit public access to computer-based information sources. Pages of information from a data base can be selected by commands issued by the user via a key pad. The page is then displayed on the screen of a domestic television receiver.

This paper discusses the problem of system flexibility with respect to picture description, and describes one solution which is the basis of the Canadian Telidon system. Various user-related issues concerned with requirements for the display of information and for the software interface are also presented.

Videotex is the generic name for information retrieval services that use suitably modified television receivers as the terminal display. Users of a Videotex system will be able to use a keypad or keyboard to instruct a data base computer at a distant location to send a particular image to the display. With current technology, the image must be mainly static, and may contain textual information, geometric drawings, or more complex photo-like objects. Communication with the data base computer will be mediated by telephone lines or other interactive networks. The Videotex concept is revolutionary in that the user has much more control than at present over what appears on his television screen.

Pages of information are created for the data base by using more sophisticated terminal equipment. An individual using such a terminal can make information available for profit or as a means of advertising. In the first instance, a literary author may wish to use the service as an inexpensive publication medium. In the second, a store may wish to advertise its wares. Eventually, sales may even be concluded remotely using the system if barriers to electronic funds transfer can be overcome.

As technology progresses, terminals may be able to communicate directly without mediation by a host computer. When the two displays each respond identically to instructions given at either terminal, they may be used as an "electronic blackboard" or as a means for playing a game such as chess at a distance.

The service can improve the convenience and immediacy of activities such as reading newspapers, writing letters, advertising, banking, and playing games. Public access of information will be one of the first applications of a Videotex service since many of our activities are concerned with finding out about the state of the world around us. Further, the required technology for this application is well understood. Also, because an information retrieval service can satisfy many special requirements, it has the potential for attracting a sufficiently large market.

The method of choice by Videotex proponents for accessing information is a tree-structured search technique. This approach was initially proposed and implemented by the British Post Office (Fedida, 1975). Its primary advantage is that it consumes the least computing resources while servicing a request for information. This is important when thousands of users are connected to the computer at one time. The more the computer is required to do to service requests, the longer a person may have to wait to receive the desired page, and the less interactive the system appears to the user. As an example of searching through a tree structure, a user might select "real estate" from one menu page, which is then immediately followed by another menu listing the names of areas within the city. Selection of any of these choices results in display of another page with categories of real estate such as business or residential. Selections of items on this and subsequent menus may eventually lead to a description of a house at a particular address. This information could initially have been entered either by a real estate company or by an individual wishing to sell his own property. Either could be contacted further by individuals who were impressed by the description they so conveniently discovered.

The Problem of Image Description

Two different approaches to Videotex systems have evolved in several countries such as Britain, France, and Canada. They differ mainly in how the images are coded for storage in the data base and for subsequent transmission to the terminal display. The European systems are character oriented which restricts the displays to fixed format textual messages and rudimentary graphic images. If their approach is adopted extensively, it will be difficult, if not impossible, to change to new communication methods which would allow the display of higher quality images.

The adaptability of character oriented systems to new requirements is mainly constrained by the way an image is described. Images are transmitted as sequential pieces of a picture consisting of 24 rows of 40 characters. Graphic images are similarly constructed from specially identified, coded graphic characters fitted together in a mosaic of picture components. This technique requires that the stored information includes information about the display terminal resolution. Thus, information banks would have to store multiple versions of an image to transmit to terminals with differing display resolutions.

A Videotex system suitable for today's technology should be designed so that future modifications can be easily incorporated. To ensure this compatibility, images need to be described in the data base in such a way that they are completely independent of the data access procedure, of the characteristics of the communication medium, and of the display terminal construction. These criteria are met by the Picture Description Instructions (PDIs) developed at the Communications Research Centre of the Canadian Department of Communications, and incorporated in the Telidon Videotex system (Bown, O°Brien, Sawchuk and Storey, 1978). Graphic images are described by PDIs in terms of the geometric shapes they contain. Only seven basic instructions, each followed by high resolution data, are needed to describe practically all graphic images. Four of the instructions define objects geometrically in terms of primitives consisting of lines, circular arcs, rectangular areas, or polygons. A fifth instruction indicates that the following data is in "bit" form, or photographic mode, for images where the structure cannot be defined by using the four geometric primitives. A sixth instruction defines the position of the object on the display. The seventh instruction is used for control. It usually sets a status register before other instructions are sent. For example, one function of the control instruction is to define the colour of an object. These seven instructions can describe all graphic images in a compact form for transmission to a terminal designed to interpret them.

Another command is required to change from graphic to alphanumeric mode when text is to be transmitted, and back to graphic mode for transmission of non-textual information.

The alphanumeric mode is the default mode so that a subset of the PDI set *can be used* with simple terminals which respond intelligibly only to alphanumeric information.

The proposed PDI codes can be of use only if the receiving terminal has the intelligence to interpret them and to fill the display memory with the appropriate contents. For this reason, the terminal must contain a microprocessor to perform the interpretation and generate the display memory code. The display memory itself may be either character or bit oriented. The European approach was to design character-oriented terminals. The Canadian Telidon terminal, however, uses the bit-map display memory. This means that every pixel on the display has a corresponding location in the display memory. The colour and brightness of a pixel depends on the contents of its corresponding memory location. This approach results in the need for considerably more memory than does the character oriented approach, with an accompanying increase in cost. However, the increased cost must be weighed against the benefits of a much higher resolution display. Further, memory costs continue to decrease with advances in integrated circuit techniques. Figure 1 demonstrates the quality of graphics that is possible on the Telidon system using a display resolution of 240 by 320 pixels.

Insert Figure 1 about here

The PDI code, which is the basis of the Telidon system, is an extensible code. As different uses for Videotex terminals are conceived, the code can be extended to incorporate new instructions that will facilitate such activities as generation of pictures and person-to-person communication with textual messages and graphic images.

Picture Manipulation Instructions 'PMIs) are already envisaged for use by information suppliers. These will allow a user of a Telidon-like terminal to create pictures on his television screen and store the picture descriptors in a data file. Selective erasures will be permitted as well as additions and modifications to previously created images. Further instructions can be included to permit rotation, scaling and transposition of portions of a displayed image. Instructions may even be developed to code basic speech patterns so that speech can be synthesized to accompany displayed images.

Graphic communication between individuals continues to be a subject for research at the Communications Research

Centre (Bown, O'Brien, Warburton, and Thorgeirson, 1975). Person-to-person image communication would be useful to any individuals desiring to discuss the merits of some kind of spatial organization. An example may be an architect discussing the plans of a building with a client. Applications may also appear in the sphere of entertainment as games are adapted or developed to take advantage of the visual interaction capability. As long as the picture description technique is independent of the hardware employed, future technological developments need not threaten data base obsolescence.

User-Related Issues

Advances in consumer technology inevitably raise questions of what design is most appropriate for human use. Implementation of Videotex services requires consideration of issues related to both display of information and interaction protocol, as well as identification of the most appropriate services for the medium.

Information display issues need to be addressed because the home television will be used to show static images rather than the dynamic images for which it was designed. Most human factors data related to the display issues are not directly applicable to matrix television displays. Either analogue television technology was employed, or an electronic display was not employed at all. There is no question that digital television displays have new and different characteristics that need to be studied in their own right. Further, the new technology provides the capability to do experiments that were previously difficult to do. It also permits economical use of some features such as colour. Since colour is expensive to manipulate using a paper medium, study of its full potential for coding information was not always feasible.

A number of countries are negotiating international standards that will affect how information such as text is formatted on the display, and thus, will influence the acceptability of the medium. Standards proposed by any country should be supported by relevant empirical evidence. Accordingly, we are currently studying how legibility of text is affected by various display parameters related to the density of characters on a page. Our experiments will provide a basis for a proposal regarding the maximum number of characters on a row and the maximum number of lines on a page that is suitable for North American television. However, such a standard may be applicable only under well defined conditions. For example, the optimum character density may be different for monochrome and polychrome television displays, for RF and RGB input, and for dot-matrix and in-line picture tubes. It may be different when proportional character spacing is used than when such spacing is not used. Other environmental factors such as ambient lighting, viewing distance, image contrast (both luminance and colour contrast), and screen size may also influence the optimum character density with respect to readability of text. There is also evidence that the dependent measure employed can drastically influence the conclusion of an experiment on display characteristics. Specifically, speed of reading has been shown to improve as character size decreases, while search time for a target character randomly located in two-dimensional space has been shown to decrease as character size increases (Snyder and Maddox, 1978). Thus, it may be that one character size is most appropriate for continuous text and another for graphic annotation. What appeared at first glance to be a simple question about the optimum number of characters per line and the optimum number of lines on a page, has become much more complex since various other factors must be simultaneously considered.

There are other display issues that are not directly relevant to implementation of international standards for Videotex. However, they are important from the point of view of user acceptance of the medium. Specifically, the relative merits of low versus high resolution displays should be examined considering the cost differential involved. There may well be a point above which further increases in resolution are inconsequential for most applications. Further, very little work has been done on the optimization of a lower case character set for dot-matrix displays. A number of upper and lower case fonts differing in size and shape need to be designed and evaluated for use by information providers. Design principles need to be established so that information providers can create comprehensible and pleasing pages of information. Readability can be facilitated by appropriate use of colour and spatial organization on a page. Rules for psychological closure need to be made explicit so that an incomplete concept does not remain suspended when five to ten seconds must elapse before a new page is received. The utility of various ways of scrolling text also requires examination.

Interaction protocol for information retrieval is another complex issue since it relates to data base structure, querying language and mode, input devices, and the organization of information in people's minds. Data stored in a hierarchical or tree structure is more efficient to retrieve from a technical point of view in that the least computing resources are consumed. This is an important consideration since too slow a response by the host computer can destroy the interactive feature that is intended for Videotex services. But the usefulness of a fast response is debatable when the information content of such a response is minimal. Advancing through a long series of menu pages may be analagous to conversing with a person who answers quickly but who has a very limited vocabulary. Teasing out the desired message then becomes a laborious task. The tree structure is efficient technically, but it may be very inefficient from the point of view of the user who wishes to retrieve information that has multiple attributes. Research in this area should be done given either of two assumptions: (1) the hierarchical approach is the only approach that is technically feasible, and (2) more sophisticated network structures are possible.

Under the first assumption, the research should attempt to identify rules for organizing information hierarchically so that there is the least ambiguity in people's minds regarding the correct path to take to arrive at the information they desire. That is, do different people's cognitive maps appear more congruent with some hierarchical arrangements than with others? Under the second assumption, an interdisciplinary effort is required to define the characteristics of a system that is designed for the fastest possible response to requests for information searches. Here also, the structure of people's cognitive maps needs to be studied in a general way. This kind of knowledge may aid other specialists such as systems analysts to design the most efficient means of information retrieval from the viewpoint of the user.

The language and mode (i.e., selective versus generative) of querying, and the design of the most appropriate input device are other relevant issues that are quite interdependent, and are influenced heavily by the logical structure of the information in the data base. It is probable that a considerable proportion of potential users are unfamiliar with computers, and in fact, do not wish to learn a complex procedure for accessing information. If this is true, it is up to the system designers, and possibly the information suppliers, to simplify access to information while at the same time minimizing the time to receive the desired information.

Finally, an issue which may ultimately determine the viability of Videotex services in a market controlled economy, is the way that the medium is used. The medium has several characteristics that makes it relatively unique. It is interactive, it is network-based, and it provides easy access to colour. These characteristics need to be exploited so that the medium can be seen as providing services that are both useful and unique to particular populations of users.

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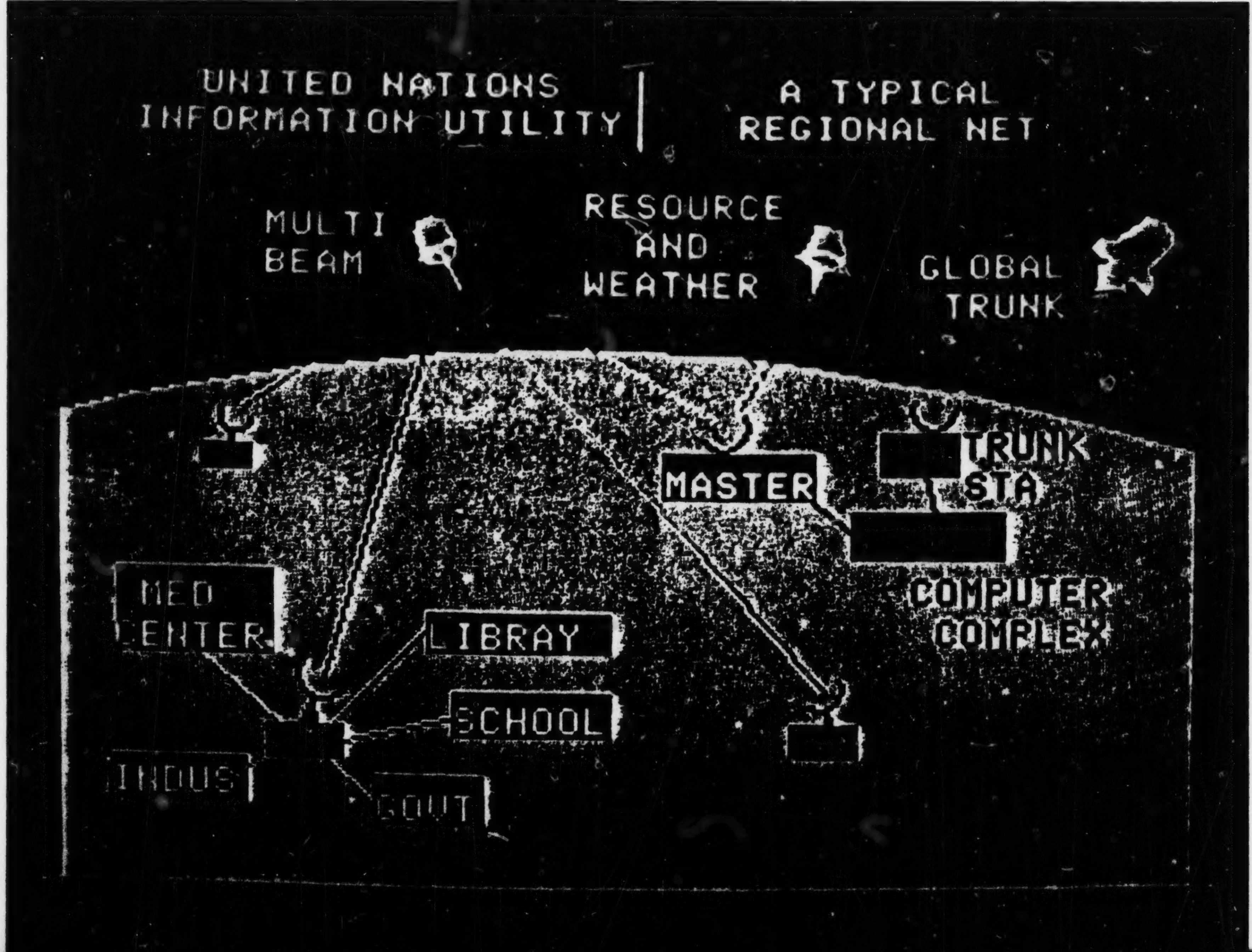
FIGURE 1


UNITED NATIONS
INFORMATION UTILITY
A TYPICAL
REGIONAL NET
MULTI
BEAM
RESOURCE
AND
WEATHER
GLOBAL
TRUNK
MASTER
TRUNK
STA
COMPUTER
COMPLEX
MED
CENTER
LIBRAY
SCHOOL
INDUS
GOVT

The Implications of Telidon for Information Science

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September, 1979

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Also available in French.

It is a pleasure to attend your meeting this evening and to discuss with you some of the implications that Telidon and similar developments have for information science. Telidon has brought to the forefront many research questions about how electronic information services should be designed to be most acceptable to users. Technology is developing rapidy and design decisions will be made even without adequate research; decisions that will affect the user and the economy. Many of the questions concern how information should be designed and indexed for easy access by users, topics which are part of your everyday work. I hope this evening to convey to you some of the excitement we feel in this research and to enlist your help in finding the answers to the questions soon enough to have some influence on the technical developments of the next few years.

Model of Telidon Research Issues

Before discussing the specific research questions about design of information banks for Telidon users, let me present a general model of Telidon research issues which will help to lend some perspective to the complexity of the questions. (Figure 1) The model shows how the various players in the development of Telidon interact and how each must consider the point of view of the others in making decisions. It may also help to remind us that there are too many questions to answer and that choosing the right questions for research will be just as important as using the right methods.

Model of Telidon Research Issues

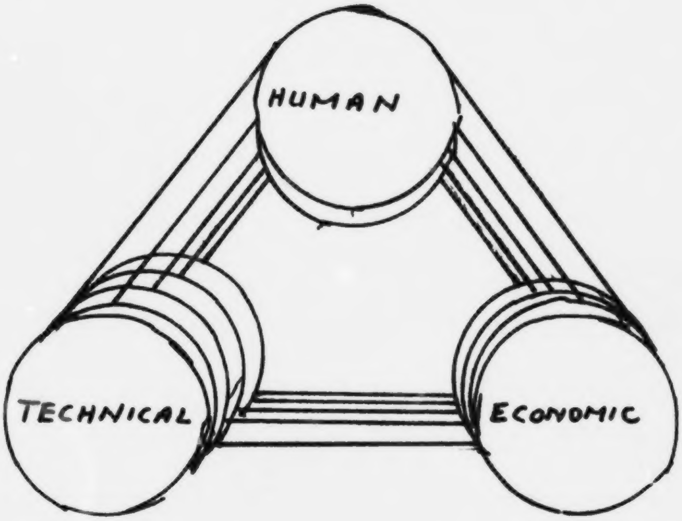
HUMAN
TECHNICAL
ECONOMIC

Figure 1

Telidon involves human, economic and technical issues. No decision can be made on any of these issues without considering its impact on the others. Each of the issues provides its own possibilities and constraints. Technical developments have been leading the way by making more things possible each year. But technical developments depend on the economy and on the abilities and limitations of humans.

Videotex technical development must appeal to users in order to make it economically viable so that development costs can be recovered and further technical development can take place. Which technical developments should come next will depend on user preferences and on how much can be done in the economic circumstances in which we find ourselves.

The diagram depicts the interaction of these three aspects of Telidon development and also the fact that changes are taking place rapidly in the technical and economic aspects. In many respects, humans do not change appreciably over short periods of time. Human perception and cognitive processing is relatively stable. Human's desires for certain aspects of culture will change as learning proceeds so there is some account taken of human changes in the model.

When we are considering which questions to study in detail it is important to remember this aspect of change in the other related areas. It may be interesting and important to know how humans react to a certain piece of technology, but if that technology is replaced next year by some other, the research may be obsolete very quickly and we will have wasted our time. We try to make research generalizable beyond any one particular piece of equipment but that is not always possible. We need to keep an eye on the future of the technology.

Most people involved in the Telidon development come from a background which stressed one of these points of view, the technologists, economists, and social scientists. Yet each of the research questions involves at least two of the perspectives of the model. The model allows us to think of the research questions at the interface of two issues while temporarily ignoring the third. This strategy seems to be necessary in view of the complexity of the problems.

As psychologists, much of our work is on the interface between the human user and the technology. While we know that our work has economic implications, we temporarily ignore them in order to define questions that are simple enough to study. Others work on the technical-economic interface and on the human-economic interface while temporarily ignoring the third point of the triangle.

I believe that much of the work of information scientists has taken one or other of the dual perspectives of human-technical or technical-economic. The remaining discussion will consider the questions that Telidon has posed on the human-technical interface, many of which are of direct concern to information scientists.

Telidon research questions on the Human-Technical Interface

The interface between humans and communications technology can be studied at a number of levels. At one level, man's ability to see and hear imposes rather strict contstraints on technical design. Since these limits are well-known, few questions remain at this level. At another level, human ability to receive and process information and to respond manually or vocally also imposes limits and it is at this level that many of the questions are now arising. At still another level, human social and cultural needs and desires suggest directions for the development of technical communications. To a large extent the questions at this level of Telidon development are still somewhat vague, and need further definition before empirical research can proceed.

Our thinking so far has concerned the human information processing level and to some extent the social and cultural desires of humans. There are three basic questions about Telidon development that I will try to describe and tell you where our thinking is at present.

1. What information should be presented on Telidon for home users?
2. How should a page of Telidon information be designed?
3. How should a tree-structure or hierarchical index be designed?

You can probably see already that these are not independent issues, the design of a hierarchical index depends on what information is in the data bank and the design of a page depends where it is to be placed in the hierarchy.

1. What information should be presented on Telidon for home users?

What we have done so far in creating a data bank for demonstration and research is to think of information that might be appealing to a fairly wide audience. We have then entered a sample of each type of information. The information bank now includes many categories: news, weather, sports, government services, historical data, consumer information, tourist guides, restaurant and entertainment guide, market place and business guide, employment service, games and cartoons, education on artificial respiration.

Another type of information that we have thought of, but not created, is a community information service which would give local events, clubs, social agencies, education facilities, laws, government services, and much other information.

All of these services are information retrieval tasks. You are familiar with other electronic information retrieval services such as bibliographic data banks. To what extent should these be made available on Telidon? Should a closed-user group service be developed for a limited set of customers? In considering that question let me refer back to the model. There are questions of each of the interfaces. At the human-technical: Can bibliographic data searches be made simple enough that the untrained user can find what he wishes in his home without technical assistance. At the human-economic: Will enough people desire the service to make it economically feasible. At the technical-economic: Can the technical interface be developed at a reasonable cost. There is much research to be done before we will know whether providing bibliographic information retrieval services to homes on Telidon is a viable service.

Telidon is constrained at present to a tree-structured data base by technical-economic considerations. This limits us to working with tree-structured information retrieval services just now. But again referring to the model, it is important to remember that changes on the technical-economic front will make available more sophisticated service offerings. When other structures become feasible for information retrieval; keyword searches or natural language queries, we will again face the questions now posed by the tree-structure and the additional question of whether these other techniques represent an improvement over the tree-structure. The answer to the latter question is likely to be complex, with other search techniques providing better service for users for some types of information.

There are also services that cannot be classed as information retrieval, that may be important applications of Telidon. Computer-aided instruction has been developing for several years and a good deal of courseware now exists. These require a full keyboardand a computer that will analyze the user's response and reply in a way that will increase learning. Most CAI programs have not used graphics and none have yet been written for Telidon. The questions we will soon face are: To what extent will people pay for CAI programs? How can we evaluate whether programs designed on Telidon will appeal to users? Can the technical development bring CAI to homes on Telidon be done within the constraints of economics?

Some thought has gone into the future of Telidon and CAI. Development of the technical requirements for creating complex CAI courses for Telidon is now taking place.

A similar analysis can be made for interactive games, a service that will require the computer to perform analyses. Games in which the user is at the helm of a system but can only control a few parameters, while many others are randomly determined, seem to be popular among computer enthusiasts. Perhaps home users would enjoy them as well.

2. How should a page of Telidon information be designed?

The page designer must know in detail the limits and capabilities of the Telidon system. At present a screen contains a maximum of 40 characters by 20 lines or 800 characters; about 120 words. But a screenfull of text is not very interesting. Graphics, color and format of the screen are important in creating an aesthetically pleasing impression and in directing viewers quickly to the important information. Telidon has 8 colours in including black and white and an additional 6 shades of grey. We have found that a page of mostly text, with more than three colours, looks somewhat confused. The designer must decide on the colour of background and text or graphics as well. The colours have different levels of brightness and it appears that the most successful combinations of background and text are those that provide the greatest contrast.

Much of what typographers and graphics designers know about formatting of text and graphics has been developed for printed material and is not directly applicable to electronic publishing. Telidon requires a set of guidelines for use of space and use of colour and character fonts. We are at work now on an initial set of guidelines but it will be some time before we have the confidence of experience in this field.

We have concentrated our research so far on problems such as how large characters should be and how they should be spaced to be most legible. We have data to show the ideal spacing of two sizes of character sets so far. Spacing parameters will be made a static part of the system so that page designers will not have to think about this problem.

3. How should a tree-structure or hierarchical index be designed?

The information provider must also be aware of the limits and possibilites of the Telidon tree-structure. The present structure allows for 9 choices on a page and is 9 levels deep. There is also cross-referencing capability and each page can also be addressed directly as well as through the tree. This basic structure leaves the information designer with several decisions to make. He must decide how many choices to put on each page of his index and how many levels deep to make the information. He may also put in documents of up to 1000 pages of sequential information. An analysis was undertaken at the Department of Communications to determine the optimum number of choices on a page. Taking account of the time to read the alternatives and the time to access each index page, the model calculates the number of choices on a page which will reduce the total search time to a minimum. According to this model, the optimal number of choices on a page is from 3-6. More than 10 choices appear to increase the search time significantly. We have not yet tested this model empirically.

Another decision the tree-designer must make is what categories to form and what labels to use for them in order to fit his material into a hierarchy. Such tasks are often assisted by the use of a thesaurus. We have looked at various thesauri to see what assistance they might be but in most cases they are only 2 or 3 levels deep and in any case the information covered does not seem to suit the material we have decided to enter into the demonstration data base. We have looked also at how these thesauri were formed with a view to forming our own. However, it seems that most of them were formed from previous lists of terms used or from a well-known set of information which has a fairly constant set of categories established,such as a newspaper.

In creating the Telidon data bank we have no such established set of information. The data bank has grown as we thought of new information to add. As necessry, we have added categories above the information as it was created and we have created new information lower in the tree to fill out the obvious related categories. It is like building a tree from the middle by going in both directions at once. This does not necessarily produce an orderly structure. We have now begun to study the tree-structure of the demonstration data base to see where people make the most errors in attempting to find information. By studying small questions that we can answer quickly, we hope to see how the tree-structure works and to learn to make some generalizations about how to build a successful tree-structure.

In conducting these studies we have considered some of the measures of information retrieval systems found in the information science literature. Measures of recall[1], precision[2], and the novelty ratio[3] have not been useful because they assume that the user is searching for a set of documents. For Telidon, we have assumed that the user is searching for a single document. We have thus used measures such as time to reach relevant material, number of errors, and attitudes of users. If our data bank were larger, it might be reasonable to assume the user would look for a set of documents rather than just one. The question of appropriate measures to evaluate Telidon data banks is still very much open.

Part of the effort to understand how to create a Telidon hierarchical data base is to determine whether it is possible to have some standard form of such data banks. A standard data bank structure across the country would allow people to know where to look for information if they moved from one part of the country to another. While this seems on the surface like a good idea, a real understanding of how to proceed to set such a standard, or what a standard would consist of, has eluded us so far. Perhaps a standard would consist of a thesaurus or of several thesauri, or perhaps it should consist of a set of guidelines about how to organize the information.

[1] recall proportion of the relevant material contained in a data base that is recalled in a search.

[2] precision proportion of material recalled in a search that is relevant.

[3] novelty ratio proportion of items retrieved and judged relevant by a user of which he was not previously aware.

This effort to prepare hierarchical data bases may have only a short useful life. If technology develops quickly so that we may use network, keyword and natural language structures, these efforts may become obsolete. But the remaining question, after the new technology becomes feasible, is whether users will still want a hierarchical data bank or whether the newer methods are more suitable for users. The answer may depend on the type of information contained in the data bank. And here we have come full circle to the original problem of what information is to be presented on Telidon.

In summary, in each area of Telidon development, the human, technical and economic factors interact in complex ways. Work on the human-technical interface has centred on how the technology relates to human capacity for information processing. The major questions to be decided in the near future are: what information should be provided on the Telidon system, how should a page of information be designed and how should a hierarchical data base be developed when it is not clear at the beginning what information will be put into it.

Within a few years, it will be important to know whether users want to use search structures other than hierarical, whether other services such as computer-aided instruction and bibliographic data bases will be useful applications of Telidon.

All of these are complex questions and important to the future of Telidon and the electronic information industry. I hope you will want to participate in finding the answers to them.

CHAPTER II

HUMAN FACTORS RELATED TO VISUAL DISPLAYS

Spacing of Characters on a Television Display
(5x7 Character Set)

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Preprint

This paper was presented at the Conference on Processing of Visible Language at Niagara-on-the-Lake on 4 September 1979, and will appear in the Conference Proceedings.

Summary

The planned introduction of videotex services in a number of countries requires that an international standard be negotiated concerning the spacing of characters and lines on a television display. This paper suggests appropriate values for the space between 5 X 7 characters both horizontally and vertically, as well as the distance by which a descender character protrudes below the line. Recommendations are based on human performance measures obtained from a letter search task. When the environmental conditions present during the experiment are approximated, the recommendations are as follows:

(a) Vertical Spacing

The recommended space between lines is three pixels (picture elements) if reading speed is important. Reading accuracy is not affected by the space between lines.

(b) Horizontal Spacing

The recommended space between adjacent characters is two pixels.

(c) Descender Length

The minimum distance that a descender should protrude below the line is one pixel. Descender characters that do not descend below the line were judged unsatisfactory.

The above recommendations can be easily translated into number of characters on a line and number of lines on a page that has a height of 240 pixels and a width of 320 pixels. When the 5x7 character matrix is increased in width by two pixels and in depth by four pixels, the result is a 7x11 matrix. This size permits display of 45 characters/line and 21 lines/page. Unfortunately, the complete display area is usually not visible on domestic television receivers due to overscan. Studies made by others in the Department of Communications indicate that overscan is probably about 10% of the picture height and width. Consequently, the useful picture dimensions are reduced to about 216 pixels by 288 pixels. The 7x11 matrix size permits display of 19.6 lines of 41 characters/line in this area. If slightly less overscan is assumed in the vertical direction (i.e., 8.3%), the recommendations permit display of 20 lines of 40 characters/line in the visible display area.

A vertical spacing of one pixel reduces the matrix size to seven pixels by nine pixels. This dimension is required to display 24 lines of text per page. However, the results show that speed of reading is significantly reduced when only one pixel separates successive lines of characters. The reduced speed is evidence that greater effort was required. Thus, more reading fatigue is expected with 24 lines/page than with 20 lines/page.

In conclusion, the experimental results indicate that 40 characters should be displayed on a line of text, and 20 lines should be displayed on a page. Further, the three pixels between successive lines can be used to create accent marks for a language such as French.

A number of countries, including Canada, are currently introducing a type of videotex service to the public. This service permits a user, either at home or in a business environment, to view information received from a data base on a raster television display. Some of this information can be pictorial, but much of it will likely be in the form of text to be read. Because communication often crosses national boundaries, it is necessary that a common standard be agreed upon for the display of text pages. That is, when a page containing text is created in one country, the format should appear the same when that page is displayed in another country. An international standard should, therefore, address the issues of horizontal character spacing, spacing between successive lines, and the degree to which descender characters protrude below the line. Appropriate values for these parameters are suggested here based on behavioural measures obtained in the laboratory.

Since people will be reading from the television display, the most appropriate measure appears at first glance to be a measure of reading rate or comprehension. Tinker (1965) reviews a number of studies that used speed of reading (SOR) as the dependent measure to evaluate various characteristics of the printed page. His experiments typically employed large numbers of subjects to compare such characteristics as type font, page colour and ambient lighting. The Tinker Speed of Reading Test (1955) demanded little in terms of comprehension. Consequently, it was thought to be sensitive to changes in perceptual input. More recently, Snyder and Maddox (1978) used a modified form of the same test to demonstrate the effect on reading performance of variations in the appearance of dot matrix characters drawn on a CRT display. Specifically, a larger matrix element size increased reading time, a square element shape reduced reading time relative to elongated shapes, and increases in the space/element size ratio increased reading time. However, studies in our own laboratory have found the SOR test to be insensitive to the effect of presenting text in upper or lower case either on paper or on a television display. Previous work comparing the effect of upper versus lower case on reading rate indicated that lower case text is read more quickly than upper case text at normal reading distances (e.g. Breland and Breland, 1944; Paterson and Tinker, 1946; Warren, 1942). Our failure to find the effect thus questions the reliability of the SOR test. At least some of the early work, as well as the Snyder and Maddox (1978) study employed between-subject designs whereas our work used completely within-subject designs. Thus, our results may have been influenced by carryover effects. If the test is reliable only when used in a between-subject design, it is not an efficient tool with respect to the number of subjects required, and alternate methods should be considered when a large number of experimental conditions are to be tested.

Another method that has been used to evaluate display quality employs a search task. The dependent measures in this case are the time to locate a specified target following presentation of the display, and the frequency of incorrect target identifications. The validity of search time as a measure of display quality for reading text is a question that deserves serious consideration. Snyder and Maddox (1978) show that manipulations of their independent variables affecting character size result in opposing effects on menu search time and reading time. Specifically, larger characters are identified more quickly than smaller characters when contextual aids are minimal, but are read less quickly when in the presence of a semantic context. Snyder and Maddox (1978) suggest that reading time is increased when characters are larger because more eye fixations are required to cover the larger area. On the other hand, search time is decreased when characters are larger because larger characters are more easily detected in the visual periphery. These findings question the appropriateness of using a menu search task such as theirs when one is interested in generalizing to reading performance.

Although the search measure reflects the legibility of individual characters, how it relates to reading performance will depend on how well the search task approximates the mechanics of reading and on the importance of individual letters as an aid to reading. Various other features at the word, syntactic and semantic levels are available to experienced readers and may facilitate the extraction of meaning from print. This is suggested by the effect of destroying word shape by alternating the case of component letters, or destroying interword boundaries by filling or removing spaces between words. These manipulations detrimentally affect both reading and search rate when the search target is a particular word (e.g. Fisher, 1975; Spragins, Lefton and Fisher, 1976; Fisher and Lefton, 1976). Further, Malt and Seaman (1978) demonstrated that improvements in reading performance when a particular filler was used to eliminate word boundaries was specific for that filler. That is, when it was replaced by a filler with a different shape, performance fell drastically to its initial level. This indicates that a letter by letter strategy is used when reading text without word boundaries. However, the result does not prove that a letter by letter strategy is used when reading normal text. In fact, Wheeler (1970) suggests that higher level features such as those found in digrams and trigrams probably aid in word recognition. Similarly, Dunn-Rankin (1978) reports that "letter combinations, either adjacent or separated in the word, are important visual cues used in word recognition". This conclusion resulted from analyses of word groups categorized in terms of similarity. However, the most dominant visual characteristic when comparing words was found to be the beginning letter.

Mason (1975) studied the effect of spatial redundancy in identification of letter symbols. Spatial redundancy was defined as "a correlation between distinctive features of letters and the positions they most frequently occupy in printed English words". Good readers were more sensitive than poor readers to the spatial redundancy of single letters in nonword letter strings. Further, good readers searched word anagrams for targets faster than they searched the words themselves if the anagrams were more spatially redundant. The confounding effect of sequential redundancy was removed in another experiment (Mason and Katz 1976) that used non-alphabetic symbols instead of letters. In this experiment, spatial redundancy was affected by controlling the probability of occurrance of a symbol at a particular location in a six symbol string. Here also, spatial redundancy was of more benefit to good readers than to poor readers although both groups were equivalent in the no-redundancy condition. Thus, positional expectancy seems to be used by good readers over and above discrimination of visual features. It appears that single letter identification is a component skill of reading in that a letter must be identified before its location can be of some use.

The preceding discussion is not all inclusive of the literature that may be relevant. However, it is sufficient to show that reading skill includes the ability to extract information from individual letters as well as combinations of letters in a familiar context. Thus, an evaluation of character and line spacing may be performed using the individual letter as the unit of analysis. Selection of an appropriate task is facilitated by considering (a) why spacing may have differential effects on perception, and (b) the mechanics of reading.

There is some psychophysical evidence that foveal sensitivity is not independent of events occurring in the visual periphery. For example, Breitmeyer and Valberg (1979) found that sensitivity to a test flash is reduced in the region of the fovea when the periphery is stimulated by an oscillating square-wave grating. Further, Mackworth (1965) reports that the addition of extraneous letters to a display severely affected a subject's ability to accurately compare a letter at the fovea with two letters presented in the periphery. Mackworth (1965) uses the concept of the "useful field of view" to interpret his finding. The useful field of view is centered at the fixation point. When there is too much information, the useful field contracts to prevent over-loading of the visual system. Therefore, when spacing between characters and lines is reduced, the size of the useful field of view should contract resulting in a slower scanning rate during reading. The slower rate would be a consequence of both reduced peripheral information and reduced foveal sensitivity. However, the increased number of characters within a given area would likely compensate for the effect of reduced peripheral information.

A task suitable for studying character spacing on a page of text should be similar to a reading task where multiple lines of characters are present. The normal mechanics of reading English text suggest that the task should involve left to right movements of the fixation point along the line of characters. If a search task were employed with such a display, it would be possible to show variations in scanning rate along a single line both in terms of distance traversed and characters read. Characters may be processed more slowly when they are farther apart because a greater distance must be scanned. However, scanning rate in terms of distance per unit time should increase as character spacing increases in order to maintain the rate of character processing. The distance scanned per unit time should increase until the trade-off between horizontal character spacing and speed of eye movement results in input of the maximum amount of accurate information with the least amount of effort. This point should, by definition, be correlated with the lowest error score.

The Experiment

The displays presented to each of the ten subjects who participated in the experiment were similar to that shown in Figure 1. The figure is a photograph of a television screen and shows the 5x7 character set employed. The letters in the display were selected randomly by a computer algorithm from the entire lower case alphabet. The critical line to which the subject was required to attend was marked in the left margin by a "plus" symbol. Because the length of the descender on the letters "g", "j", "p", "q" and "y" was a variable of interest, these five letters were selected as the search targets. The first letter in the critical line was always one of these five letters and indicated to the subject at the beginning of each trial which letter was the target. The subject's task was to immediately scan the critical line for the next occurrance of the target letter. When that letter was located, the subject was asked to say the immediately following letter. In the figure where the target is the letter "q", the response would be the letter "v". The subject was further requested to scan the line only once. If the end of the line was reached without identifying the target letter, the subject was requested to give the end letter as his response. The target letter occurred only once on the critical line following the initial cue, and the two indicated response letters were also unique in that line. The subject was further instructed to attempt to regulate his scanning rate so that targets were missed on no more than 10 percent of the trials. Display onset was relatively instantaneous and activation of a voice switch by the response resulted in erasure of the display. Response time was measured to the nearest msec and the actual response was entered at the computer console by the experimenter during the three second inter-trial interval.

The 5x7 character matrix spanned 10 picture elements (pixels) horizontally and was displayed on 14 television scan lines vertically to minimize the flicker that would result from displaying each dot of the matrix on only one field of the television frame. During the experiment, a Conrac Model RHN 19/C 19 inch colour television monitor was employed. This monitor has circular phosphor elements arranged in the usual triangular pattern. The letters were always displayed in white on a colourless background. The white colour was calibrated at a colour temperature of 6500 degrees and the display intensity when fully illuminated was adjusted to be 14 foot lamberts. Ambient room lighting was approximately 34 foot candles.

The subject was seated approximately four feet from the display without a head restrainer. A page was displayed to facilitate explanation of the task by the experimenter, and then 10 trials were presented for practice. The experiment itself was a 3x3x3 within design with length of descender, horizontal spacing and vertical spacing as the three factors. Length of descender refers to the amount of protrusion below the line by descender characters and was 0, 1 or 2 pixels. Both vertical and horizontal spacings were 1, 2 or 3 pixels. Therefore, the total design consisted of 27 cells. Each of the five target letters was presented twice in each experimental condition. The 27 conditions were randomly ordered within each of 10 blocks of trials. Thus, the total number of trials for a subject was 270. Because the session lasted about 35 minutes, a short pause was permitted following the 135th trial.

A repeated measures analysis of variance was performed on each of three dependent variables: (1) frequency of misses, (2) scanning rate in characters/sec, and (3) scanning rate in pixels/sec. Analysis of frequency of misses showed a significant effect due to horizontal spacing ($F(2,18)=5.598$, $p<.05$), and an effect due to length of descender ($F(2,18)=15.944$, $p<.01$). No interactions were significant. Analysis of scanning rate in characters/sec showed a significant effect due to vertical spacing ($F(2,18)=5.374$, $p<.05$), horizontal spacing ($F(2,18)=42.720$, p<.01) and length of descender (F(2,18)=15.745, p<.01). No interactions were significant. Analysis of scanning rate in pixels/sec showed a significant effect due to vertical spacing (F(2,18)=5.60, p<.05), horizontal spacing (F(2,18)=205.325, p<.01), and length of descender (F(2,18)=18.321, p<.01). Figures 2, 3, and 4 show the means corresponding to the above effects. Table 1 shows the proportion of the total variance explained by each of the significant effects.

Table 1

Percentage of Total Variance Explained

	Variable		
	Miss Frequency	Character per sec	Pixels per sec
Vertical Spacing	---	1.3	1.1
Horizontal Spacing	4.3	6.6	16.6
Descender Length	7.2	3.2	3.2

The statistical significance of differences among the means was tested using the Newman-Keuls procedure (Winer, 1962). A "non-descending" descender character resulted in significantly more misses than did descender lengths of one or two pixels. There was, however, no significant difference between the latter two descender lengths. Similarly, the lack of a descending component was related to a significantly slower scanning rate than were descender lengths of one or two pixels. Again, there was no significant difference between the latter two descender lengths. These findings suggest that the descending component of a descender character should protrude below the line by at least one pixel.

The reason for the effect of descender length is probably straightforward. That is, a descender that protrudes below the line by even one pixel is a distinctive enough cue to facilitate the accuracy and speed of detection of that character, given that a descender character had a less than .2 a priori probability of occurring.

The amount of space between lines of characters appeared not to affect the frequency of missed targets. However, there was an effect on the rate of scanning the line. That is, a vertical spacing of three pixels resulted in significantly faster scanning of the line than did spacings of one or two pixels. There was no significant difference between the latter two conditions. These findings permit some leeway in judging what the minimum spacing should be. Specifically, if scanning speed is not a requirement, it appears that the minimum spacing of one pixel is adequate. However, if the faster scanning is a criterion, a spacing of at least three pixels should be maintained between lines. If the faster scanning occurred because less effort was necessary to identify letter features, it may be that lines of text separated by at least three pixels are less fatiguing to read than lines separated by one or two pixels.

It is not immediately obvious why the spacing between lines should affect the rate of scanning in the horizontal direction. It is possible that the reduction in the density of visual "noise" in the periphery that results from increasing the spacing between lines, enlarges the "useful field of view" (Mackworth, 1965). If the useful field of view is enlarged in at least the horizontal direction, increased use of peripheral information in the direction of scanning might result in faster scanning rates.

A space of one pixel between characters on a line (horizontal spacing) resulted in significantly more misses than did spaces of two or three pixels. There was no significant difference between the latter two spacings in the number of search targets missed. Analyses of the two rate measures showed that all three spacings were significantly different from each other. However, the number of characters scanned per second decreased with increasing spacing, while the number of pixels scanned per second increased with increasing spacing. Obviously, the highest character rate occurred at the smallest spacing because the most characters were squeezed into a unit distance. When the spacing between characters was increased, the average eye movement velocity, reflected by the pixel per second measure, also increased. However, the increased rate of eye movement did not become sufficiently high to maintain the rate at which characters were processed at the smallest spacing. This is shown in Figure 5 where the dotted lines show the number of characters that should have been processed per second if the rate of eye movement had remained the same as it was with a horizontal spacing of one pixel or two pixels. The significantly increased number of missed targets at a spacing of one pixel may be taken as evidence that characters were being processed at too high a rate. Therefore, the miss frequency data suggests that a space of at least two pixels should separate characters to maintain accurate letter identification. A further increase in spacing will significantly increase the velocity of eye movements, but will nevertheless result in a reduced rate of input of characters. The latter is an important point for it is characters and not distance per se that yields information during reading.

The effect of horizontal spacing on rate of scanning characters can be attributed to the change in density of characters within the fixation area as horizontal spacing is varied. The high density with the shortest spacing appears to demand an undesirably high processing rate as indicated by the accompanying higher miss frequency. The density at the intermediate spacing does not appear to be excessively high however. If it were, the significant increase in rate of eye movement should not have occurred. Further, the miss frequency begins to asymptote around the intermediate horizontal spacing employed. Therefore, the recommended minimum horizontal spacing of two pixels probably arises from a limitation on the rate of human information transmission. This conclusion suggests the need for caution in applying the recommendation for horizontal spacing from this experiment to a page of text with all its redundancies and higher order features. When the unit of analysis during reading can vary from the single letter to the word or phrase level, the effect of a space of only one pixel between characters may be undetectable.

Conclusions

Recommendations regarding the minimum required spacing between characters and between lines, and the minimum required distance that a descender character should protrude below the line, can be made from the speed and accuracy data obtained in this experiment. The recommendations are relevant for the presentation of text on a television display when the reading distance is approximately four feet, the characters are designed on a 5x7 dot matrix, the character matrix spans 14 television scan lines, and the phosphor elements are round rather than oblong. The recommendations apply to the display of text since other literature indicates that letter identification is a significant component of reading skill. The recommendations are as follows:

(a) Vertical Spacing

The results indicate that accuracy is not influenced by the space between lines even when it is as little as one pixel. However, letter reading speed, and possibly ease of reading, can be improved significantly by increasing the space to three pixels. Therefore, the recommended space between lines is either one or three pixels depending on whether or not reading speed is an important criterion. This recommendation is independent of the chosen length of descender. An additional advantage to using a separation of three pixels is that space is provided for accent marks for a language such as French.

(b) Horizontal Spacing

A space of two pixels between successive characters on a line is recommended. Less than two pixels results in significantly more errors in letter identification, while more than two pixels causes an unnecessary reduction in the rate of information input.

(c) Descender Length

It is recommended that the descender component of a descender character should protrude below the line by at least one pixel length. Descender characters that do not descend below the line are missed significantly more often and are identified more slowly. A descender length of more than one pixel does not improve performance significantly.

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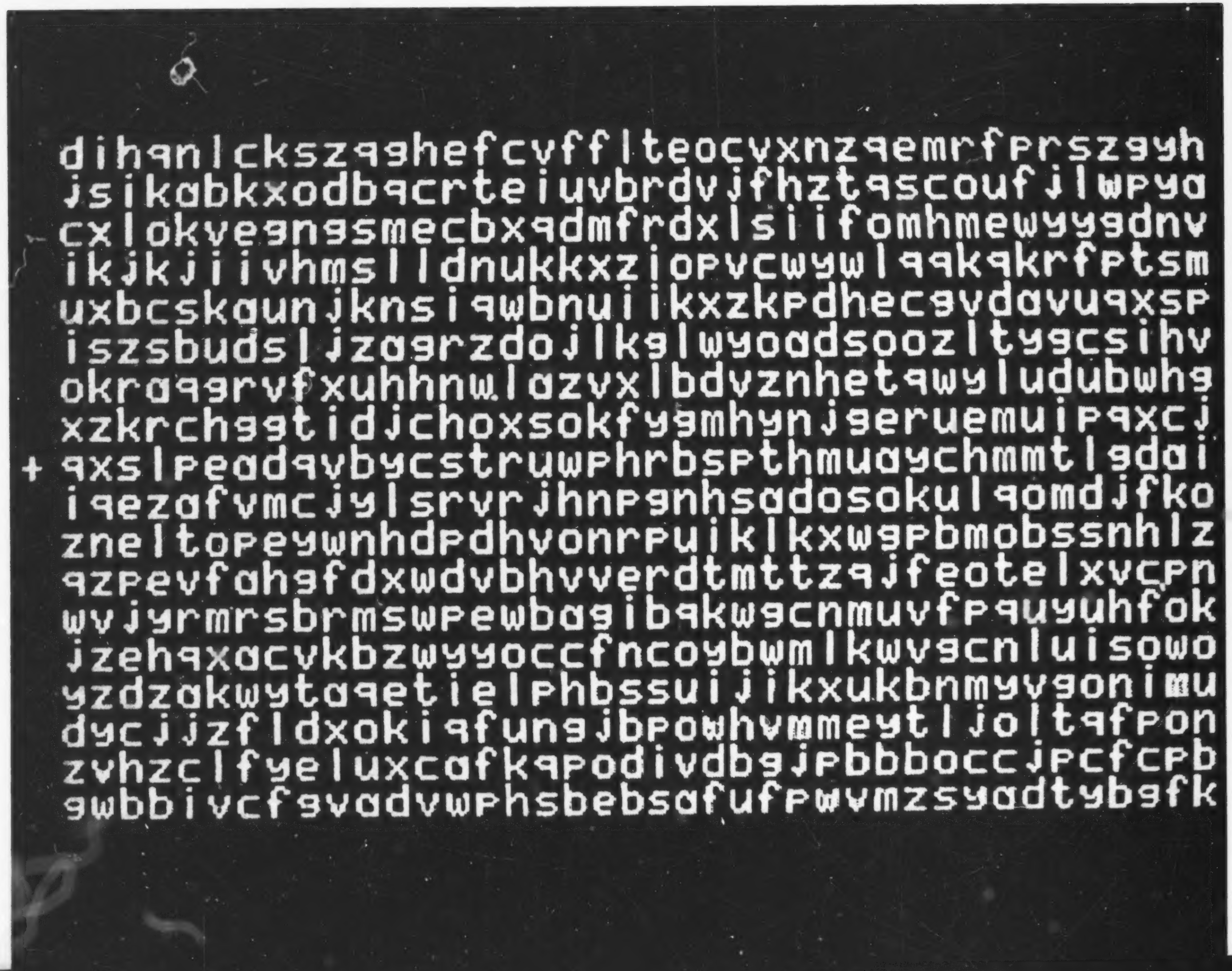
Figure 1.



```
  dihqnlckszqghefcvfflteocvxnzqemrfprszgyh
  jsikabkxodbqcrteiuvbrdvjfhztqscoufjlwpya
  cxlokvegngsmecbxqdmfrdxlsiifomhmewyygdnv
  ikjkjiivhmslldnukkxziopvcwywlqqkqkrfptsm
  uxbcskaunjknsiqwbnuiikxzkpdhecgvdavuqxsp
  iszsbudsljzagrzdojlkglwyoadsoozltygcsihv
  okraqgrvfxuhhnwlazvxlbdvznhetqwyludubwhg
  xzkrchggtidjchoxsokfygmhynjgeruemuipqxcj
+ qxslpeadqvbycstruwphrbspthmuaychmmtlgdai
  iqezafvmcjylsrvrjhnpgnhsadosokulqomdjfko
  zneltopeywnhdpdhvonrpuiklkxwgpbmobssnhlz
  qzpevfahgfdxwdvbhvverdtmttzqjfeotelxvcpn
  wvjyrmrsbrmswpewbagibqkwgcnmuvfpquyuhfok
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  yzdzakwytaqetielphbssuijikxukbnmyvgonimu
  dycjjzfldxokiqfungjbpowhvmmeytljoltqfpon
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FIGURE 2

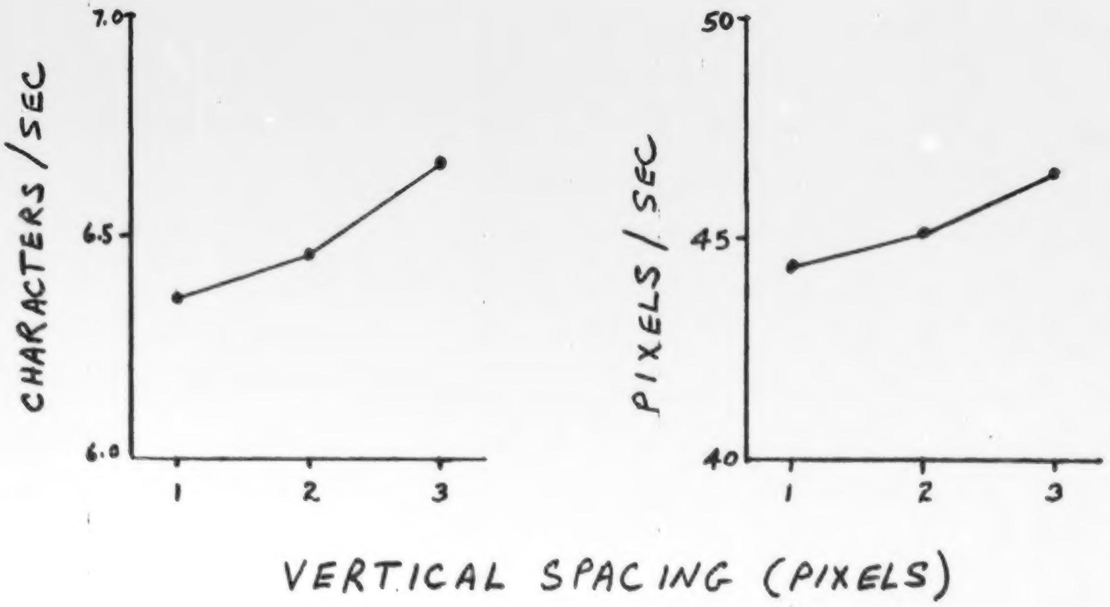

CHARACTERS / SEC
7.0
6.5
6.0
1
2
3
PIXELS / SEC
50
45
40
1
2
3
VERTICAL SPACING (PIXELS)

FIGURE 3

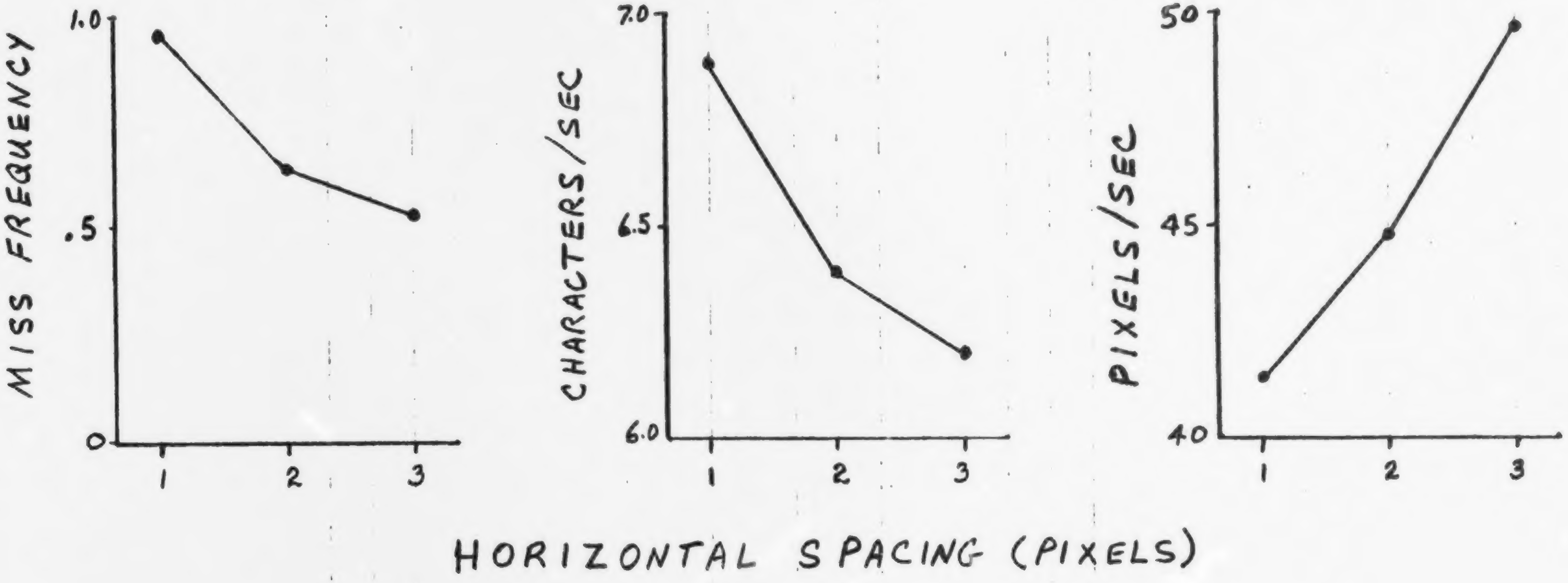

MISS FREQUENCY
1.0
.5
0
1
2
3
CHARACTERS/SEC
7.0
6.5
6.0
1
2
3
PIXELS/SEC
50
45
40
1
2
3
HORIZONTAL SPACING (PIXELS)

FIGURE 4

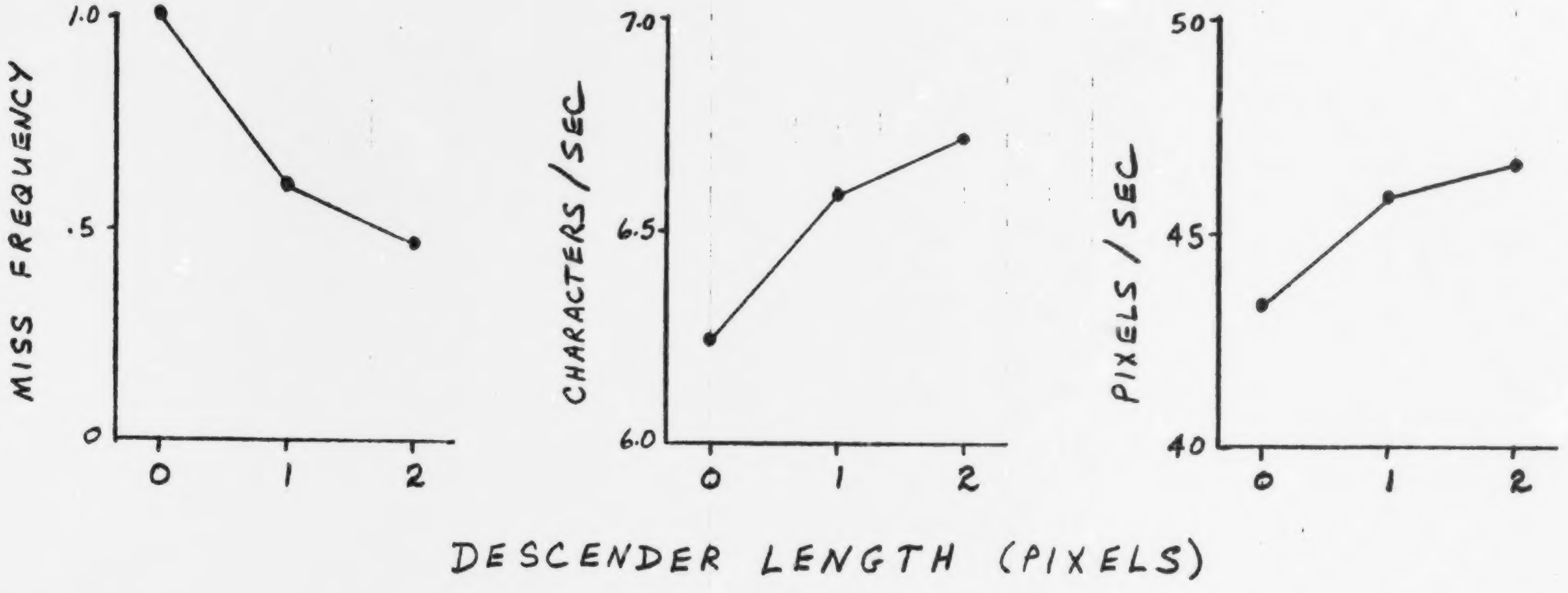
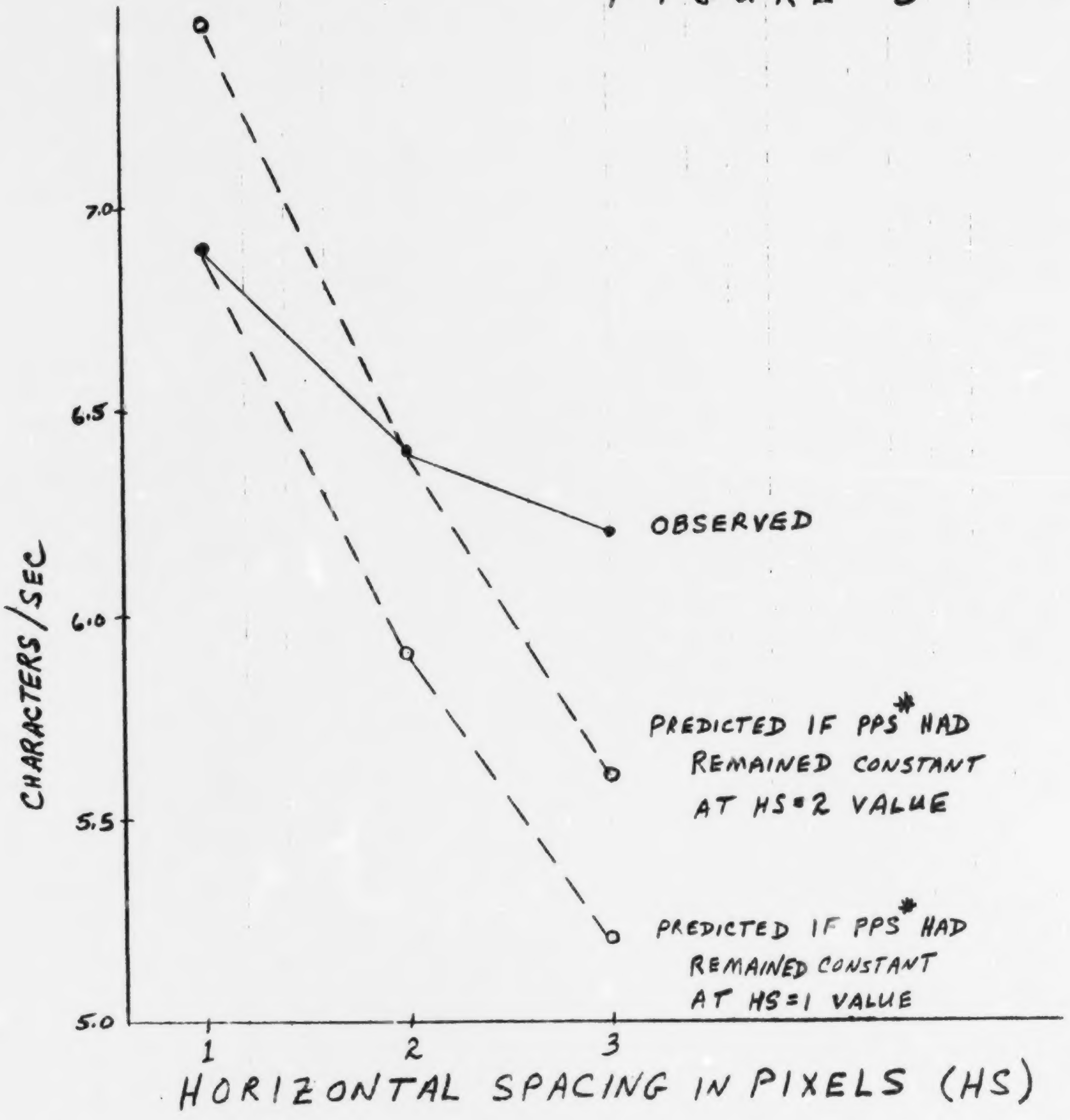

MISS FREQUENCY
1.0
.5
0
CHARACTERS / SEC
7.0
6.5
6.0
PIXELS / SEC
50
45
40
0
1
2
DESCENDER LENGTH (PIXELS)

FIGURE 5



* PIXELS/SEC

Character Sets for Videotex Field Trial Terminals

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Ottawa, Ontario

November 1979

Summary

The Behavioural Research Group at the Department of Communications examined a number of character set parameters in order to select those most appropriate for RGB and composite video input. Two English and two French character sets were selected for use in field trial terminal specifications, and close to optimal character spacings were suggested to accommodate both readability factors and design decisions based on economic considerations. It was also recommended that proportional spacing and increased character spacing be specified when word oriented free format text mode is in effect.

1. Character Sets for Field Trial Terminals

The design of characters and their organization on a page has been studied by the Behavioural Research Group of the Department of Communications (Treurniet, 1979a; Treurniet, 1979b; Treurniet and Latremouille, 1979). The aim was to define system parameters that result in the most readable text on the home television receiver to be used in Canadian videotex field trials. It was found that quite different character sets and spacings were needed to compensate for differing system limitations when the technology was varied.

When the appearance and organization of text can be ignored immediately following the extraction of meaning, it is said to be transparent. Conversely, anything that interferes with our reading habits, contributes a measure of opacity to the text (Roudiez, 1978). Unless the opacity is intended, as in some forms of artistic expression, it is desirable to minimize it so that the reader's full attention can be directed toward the task of comprehension. Opacity can result from among other things, unexpected or unaesthetic appearances of letters, words and sentences on the page. Therefore, a page of text on Videotex should be printed using a character set that compensates as much as possible for the limitations inherent in the medium.

Several experiments and demonstrations have identified character sets that are most appropriate for the two different video input modes that are being proposed for videotex systems. Composite video and RGB video are two types of video signals that have markedly different effects on displayed information. Relative to the RGB input signal, the composite video signal degrades the image by imposing limitations on both colour representation and resolution. A change in colour from one area to another causes scintillation along the vertical contour between the two areas. This effect is difficult to prevent given the way that colour is decoded from the composite video signal. The bandwidth restriction imposed by the NTSC television standards inhibits brief luminance changes that are required to adequately display vertical lines of one pixel width. The CSA-1 (English) and CSA-2 (French) character sets (equivalent to ISO 646) described below and shown in the figures in the appendices, are recommended for chromatic and achromatic RGB displays and achromatic composite video displays. Implementation of proportional spacing is required when using character set CHSET 7 described below, and it is strongly recommended for use with all character sets in word oriented free format text mode.

There may be technical and economic tradeoffs between the manner in which a terminal is constructed and the best character set specifications. The following descriptions present the most desirable specifications from the point of view of legibility. A subsequent section takes these tradeoffs into account and recommends practically realizable specifications for field trial terminals.

RGB VIDEO

CHSET 1: This CSA-1 character set uses a 5x8 character matrix. It enables display of 40 characters/line and 20 lines/page. The botton row of pixels in the matrix is used only by descender characters. It is recommended that text be displayed with two pixels separating character matrices horizontally and three pixels separating matrices vertically.

CHSET 2: This CSA-2 character set uses a 5x11 character matrix that enables display of 40 characters per line and 20 lines per page. The bottom row of pixels in the matrix is used only by descender characters, while the top three rows separate the character from the character on the line above. The same three rows of pixels at the top of the matrix are used to draw accents on 10 upper case accented characters, and the second, third and fourth rows are used to draw accents on 10 lower case accented characters. It is recommended that text be displayed with two pixels separating character matrices horizontally, and no space separating matrices vertically.

CHSET 3: This CSA-1 character set uses a 7x11 character matrix. It enables display of 32 characters/line and 16 lines/page. The two bottom rows of pixels are used only by descender characters. It is recommended that text be displayed with two pixels separating character matrices horizontally, and one pixel separating matrices vertically.

CHSET 4: This CSA-2 character set is the same as CHSET 3 except that 10 non-alphabetic characters are replaced by accented lower case characters. Accents are placed on the two top rows of the matrix. It is recommended that text be displayed with two pixels separating character matrices horizontally, and one pixel separating matrices vertically.

COMPOSITE VIDEO

CHSET 5: This CSA-1 character set is similar to CHSET 3. It differs in that all components of characters, as well as spaces within characters, are at least two pixels wide. The extra width compensates for the restriction in bandwidth of the composite video signal. Most characters in this set use only six of the seven columns of the character matrix. Therefore, in spite of the bandwidth restriction, it is recommended that text be displayed with two pixels separating matrices horizontally, and one pixel separating matrices vertically.

CHSET 6: This CSA-2 character set is similar to CHSET 5 in that all character elements are at least two pixels wide. The accented characters are similar to those of CHSET 4. It is recommended that text be displayed with two pixels separating matrices horizontaly, and one pixel separating matrices vertically.

CHSET 7: This character set was created to improve the appearance of two letters in CHSET 5 and CHSET 6. In those character sets, the seven columns were insufficient to properly widen the vertical components of the letter m and w. Therefore, CHSET 7 was designed using a 10x11 matrix. The letters m and w in both upper and lower case were designed using all ten columns of the matrix. All other characters use only six columns as in CHSET 5 and CHSET 6. Because the majority of characters in CHSET 7 leave four columns of the matrix unused, these must be removed when text is displayed by implementation of proportional spacing.

CHSET 8: This CSA-2 character set uses a 5x9 character matrix that enables display of 40 characters/line and 20 lines/page. The bottom row of pixels in the matrix is used only by descender characters, while

> the top two rows are used to draw accents on 10 lower case accented characters. It is recommended that text be displayed with two pixels separating character matrices horizontally, and two pixels separating matrices vertically.

Three levels of system implementations are implied by these character sets. At the lowest level, the terminal outputs only composite video. In this case, CHSET 5 and CHSET 6 should be used. At the next level, RGB output is available for television sets equipped to receive RGB. This configuration could use CHSET 1, CHSET 2, CHSET 3, CHSET 4, and CHSET 8. The third level would permit proportional spacing. When this capability exists in terminals that output composite video, CHSET 7 should be used in free format text mode.

Colours having adequate luminance contrast can be used to display text on RGB displays. However, the use of colour to display text on composite video displays results in considerable display instability and is not recommended.

2. Recommendations Considering Technical and Economic Factors

There is general international agreement that a line of text should contain 40 characters. This has been shown to be possible on only RGB systems. Composite video systems require larger characters due to the bandwidth limitation. The reduced number of scan lines available on an NTSC television signal makes it necessary to use less than the 24 or 25 lines of text proposed for European television systems. The maximum desirable is 20 lines. With composite video, a character set proportionally larger by a factor of 1.5 should be used (16 lines with 32 characters per line).

Behavioural studies have indicated that the space between 5x7 characters should be two pixels horizontally, that the matrix height be extended to eight pixels to accommodate descenders, and that three additional pixels separate adjacent rows of characters. These dimensions would permit 20 lines of 40 characters/line to be displayed if there were 220 by 280 addressable points on the display. Similarly, the space between 7x9 characters should be at least two pixels horizontally, the matrix height should be extended to 11 pixels to accommodate descenders, and one additional pixel should separate adjacent rows of characters. These dimensions would permit 16 lines of 32 characters/line to be accommodated on a display with 192 by

288 addressable points. Thus, in order to employ the most desirable spacings between characters and to allow for television overscan, the full display capability of 240 by 320 addressable points must be utilized to display the maximum text densities agreed upon internationally on other grounds.

However, it was decided on the basis of economy to limit the size of the television bit map memory to 200 pixels vertically and 256 pixels horizontally. This decision requires that adjustments be made either to the maximum number of characters to be displayed on a page, or to the spacing between characters. The reduction in available display area was due to the expense of display memory. Since the cost of memory is continually decreasing, this technical limitation may be relatively temporary. Therefore, it was decided to reduce the spacing between characters to a sub-optimal but acceptable compromise rather than reduce the number of characters on a line.

To meet the specifications for text density, CHSET 1, CHSET 8, CHSET 5, and CHSET 6 were chosen as character specifications for field trial terminals. CHSET 1 will have a space of one pixel horizontally between character matrices, and a space of two pixels vertically. CHSET 8 will have the same horizontal spacing, but the vertical spacing will be only one pixel since the other pixel is included in the character matrix to facilitate drawing of accents. CHSET 1 and CHSET 8 are intended for use by RGB systems only.

CHSET 5 and CHSET 6 are intended for both RGB and composite video systems. Due to the constraints on display area, both horizontal and vertical spacing will be one pixel.

The requirement for 40 characters per line only applies to annotation text where the characters must maintain a fixed spatial relationship to the rest of the display. Word oriented free format text offers considerably more flexibility. In this mode, proportional spacing can be done by the terminal, and it is strongly recommended that the horizontal spacing between all characters be increased to two pixels.

References:

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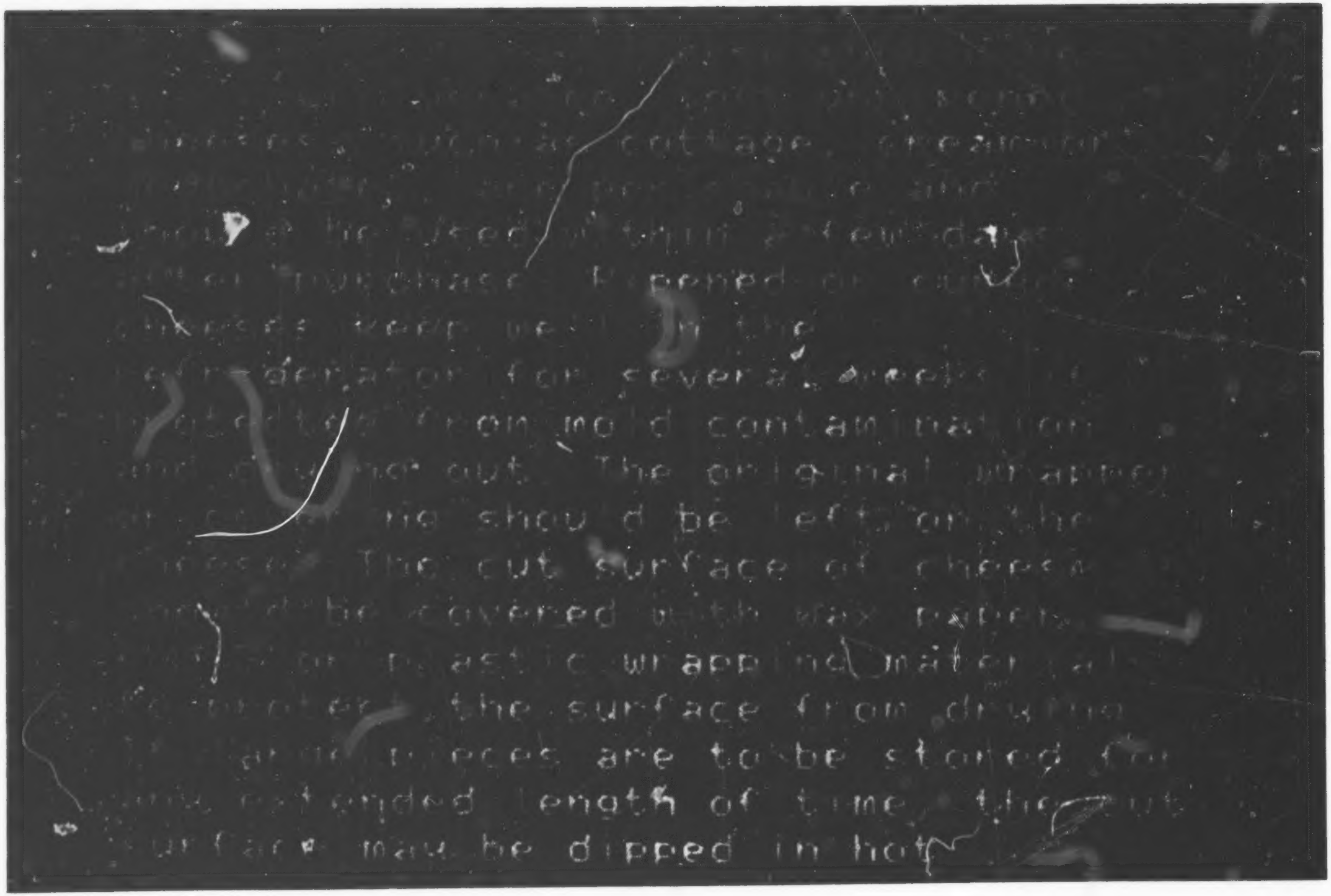
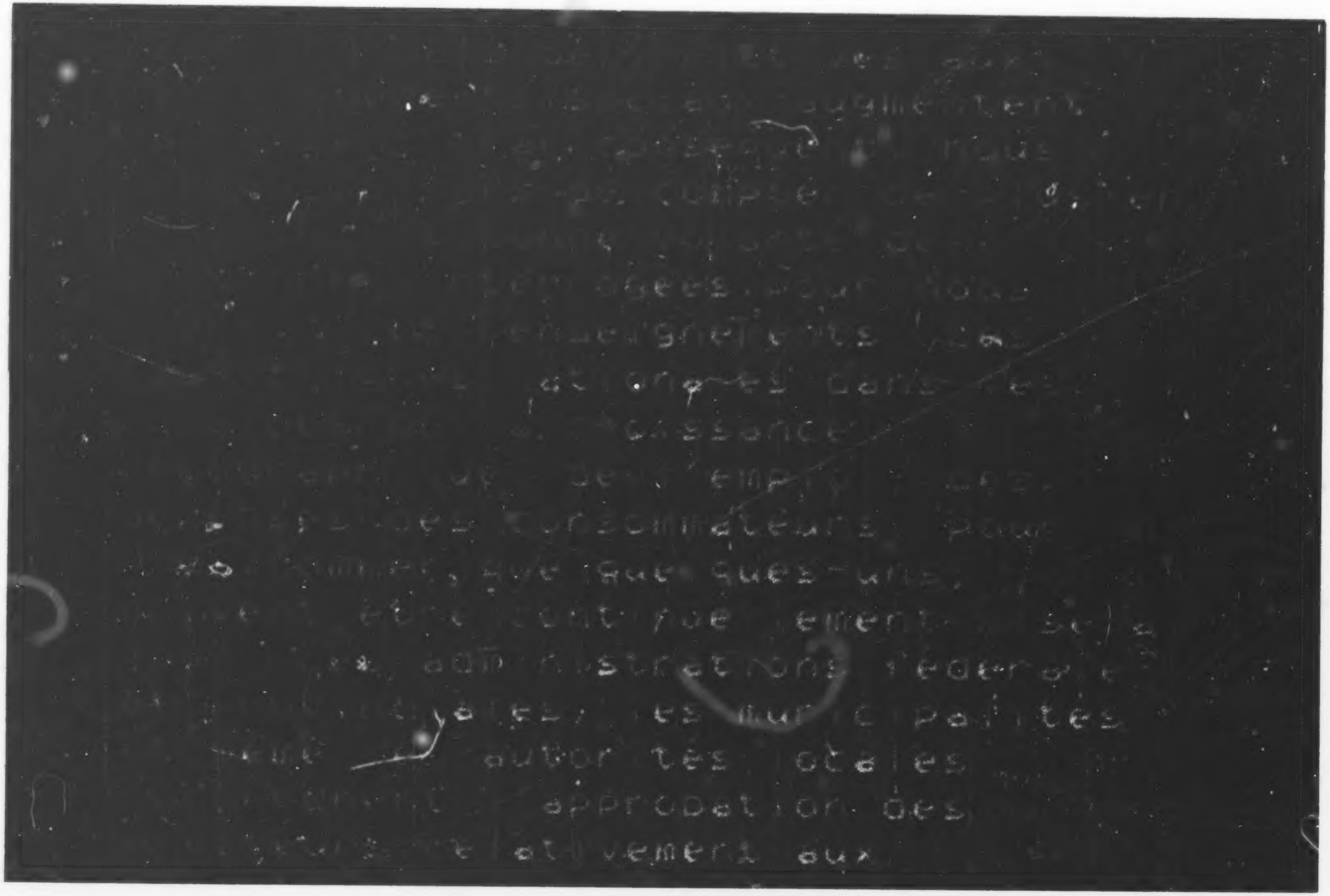
APPENDIX A

The figures in this appendix show the appearance of text using the eight character sets with the recommended spacings. The number in parentheses adjacent to each figure indicates the spacing employed. The first digit is the horizontal spacing in pixels, and the second digit is the vertical spacing. The type of video input signal is also indicated by "RGB" or "CV".



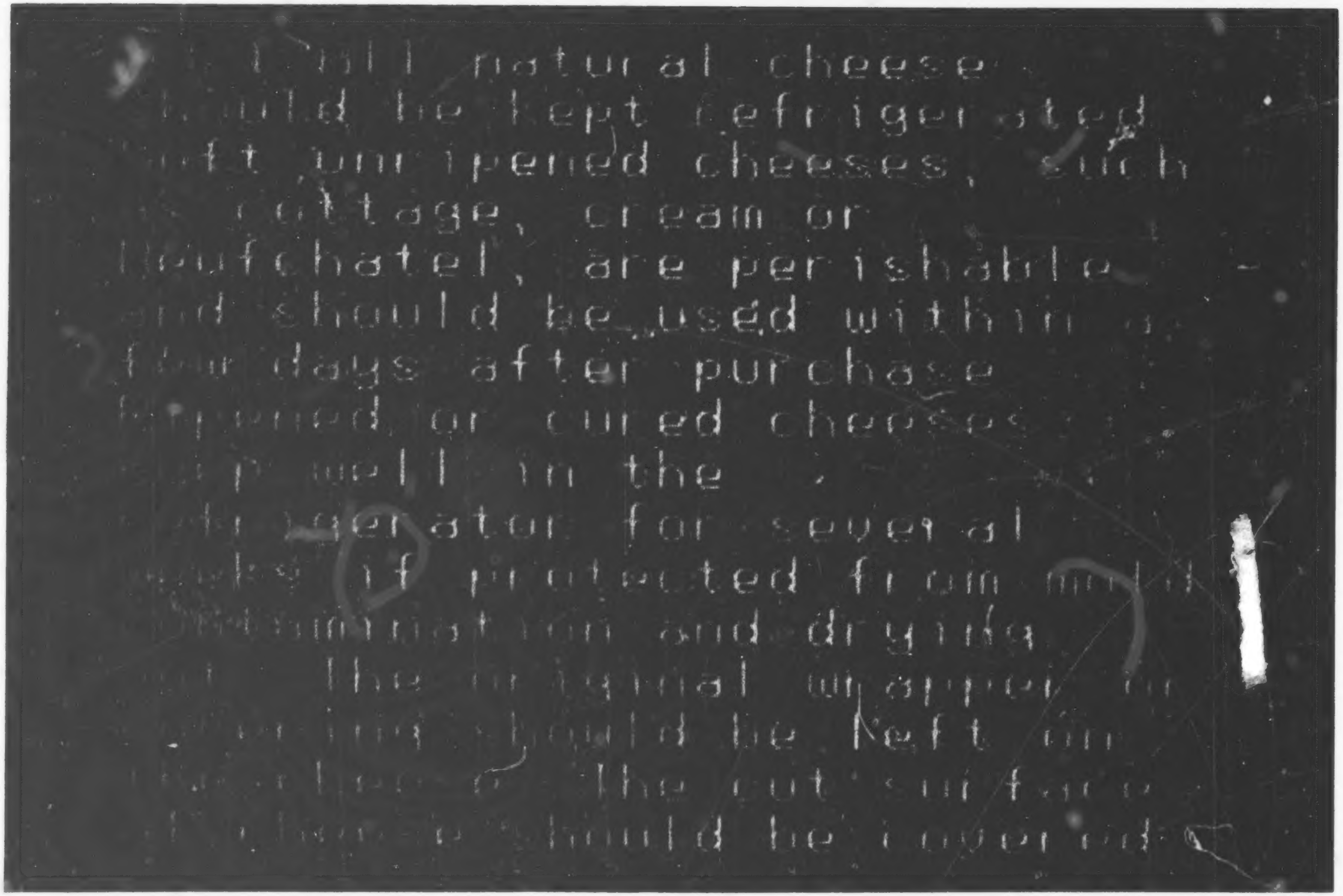
[illegible] soft
cheeses, such as cottage, cream,
[illegible], [illegible] and
should be used within a few days
after purchase. Ripened or cured
cheeses keep well in the
refrigerator for several weeks if
protected from mold contamination
and drying out. The original wrapper
or covering should be left on the
cheese. The cut surface of cheese
should be covered with wax paper,
foil, or plastic wrapping material
to protect the surface from drying.
If large pieces are to be stored for
an extended length of time, the cut
surface may be dipped in hot

CHSET 1 (23) - RGB



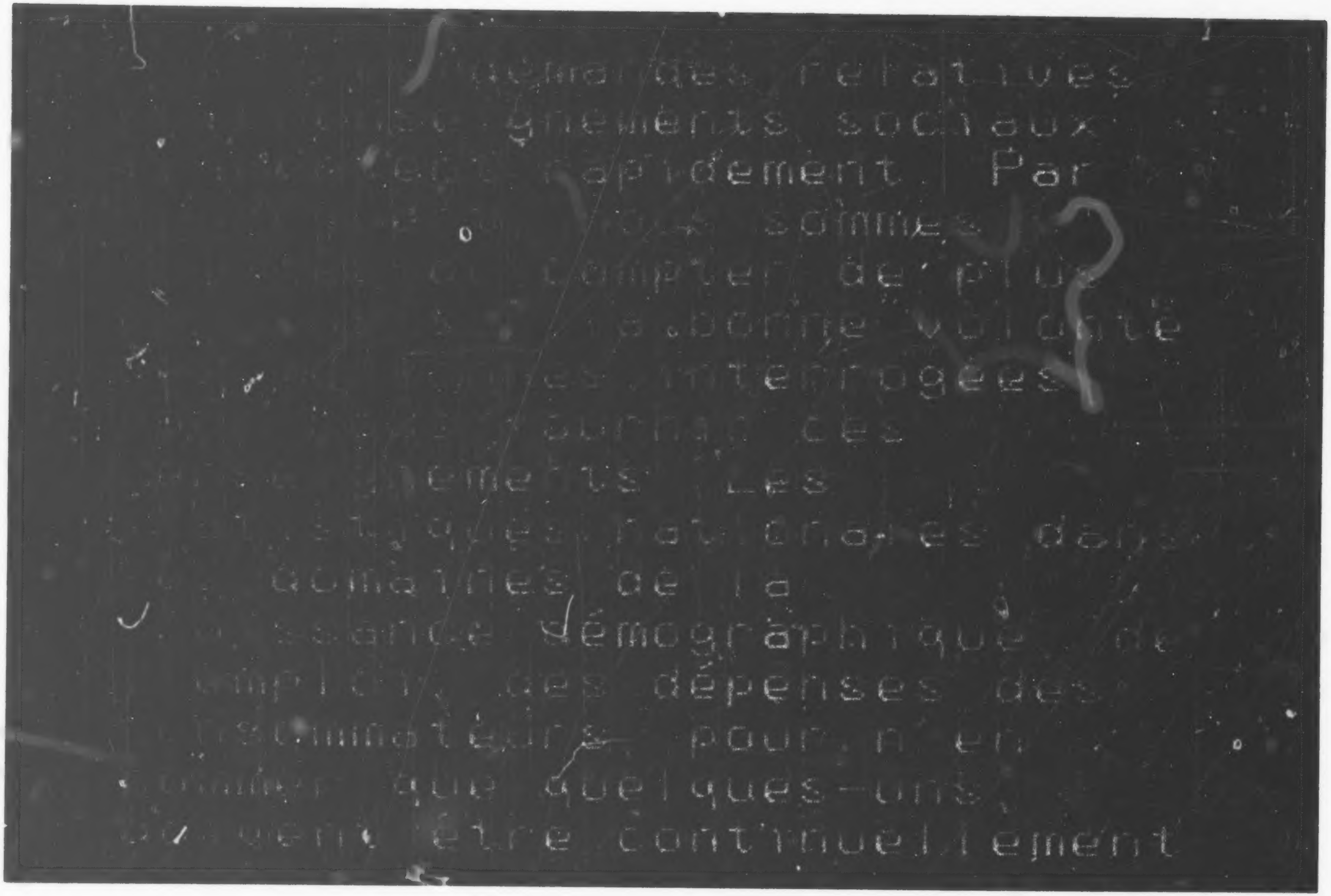
[illegible] aux
[illegible] augmentent
[illegible] nous
[illegible]
[illegible]
[illegible] pour [illegible]
[illegible] renseignements [illegible]
[illegible] dans [illegible]
[illegible]
[illegible]
[illegible] consommateurs pour
[illegible] quelques-uns
[illegible] être [illegible] ement [illegible]
[illegible] administrations [illegible]
[illegible] les municipalités
[illegible] autorités locales
[illegible] approbation des
[illegible] relativement aux

CHSET 2 (20) - RGB

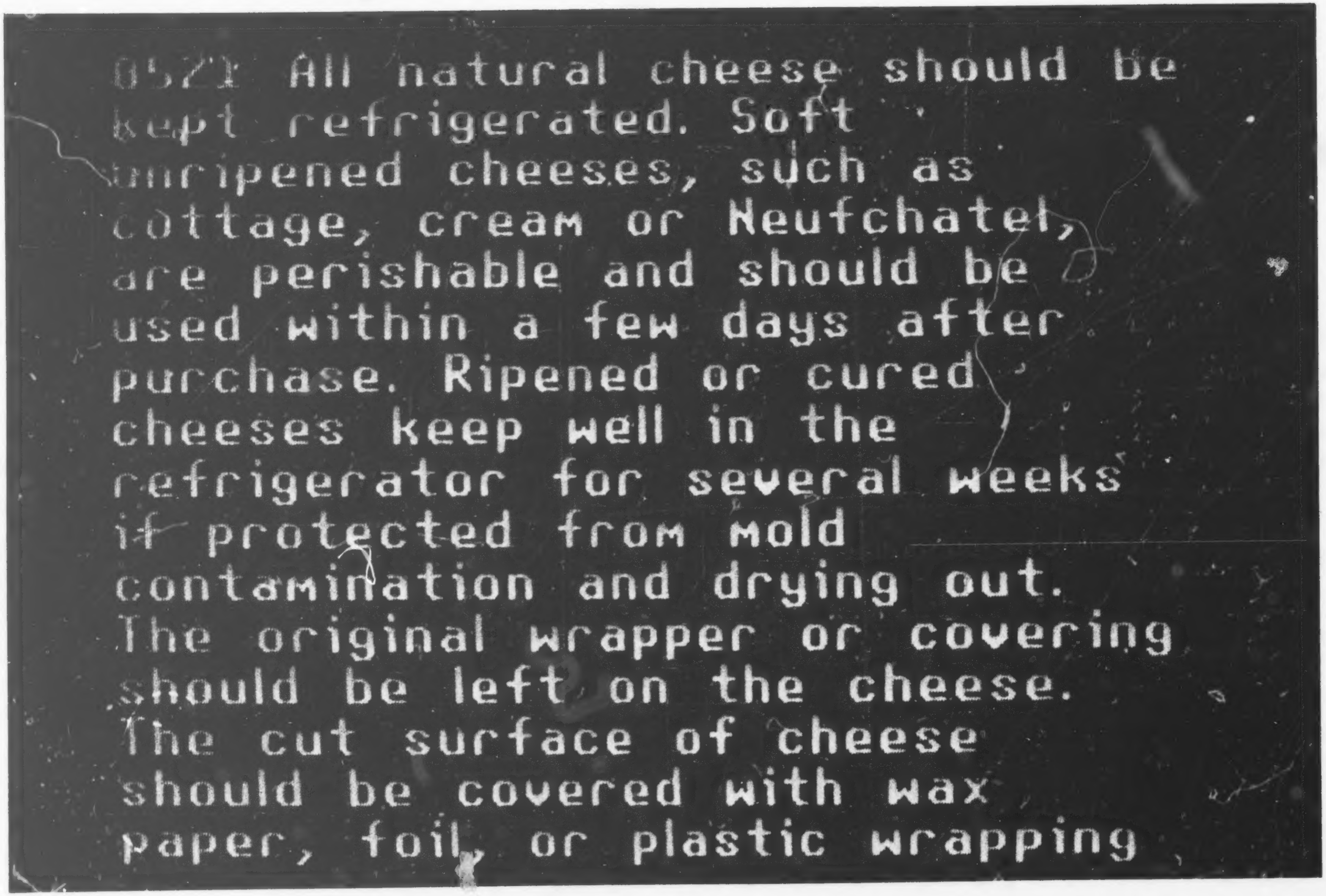


All natural cheese
should be kept refrigerated.
Soft unripened cheeses, such
as cottage, cream or
Neufchatel, are perishable
and should be used within a
few days after purchase.
Ripened or cured cheeses
keep well in the
refrigerator for several
weeks if protected from mold
contamination and drying.
The original wrapper or
covering should be left on
the cheese. The cut surface
of cheese should be covered.

CHSET 3 (21) - RGB

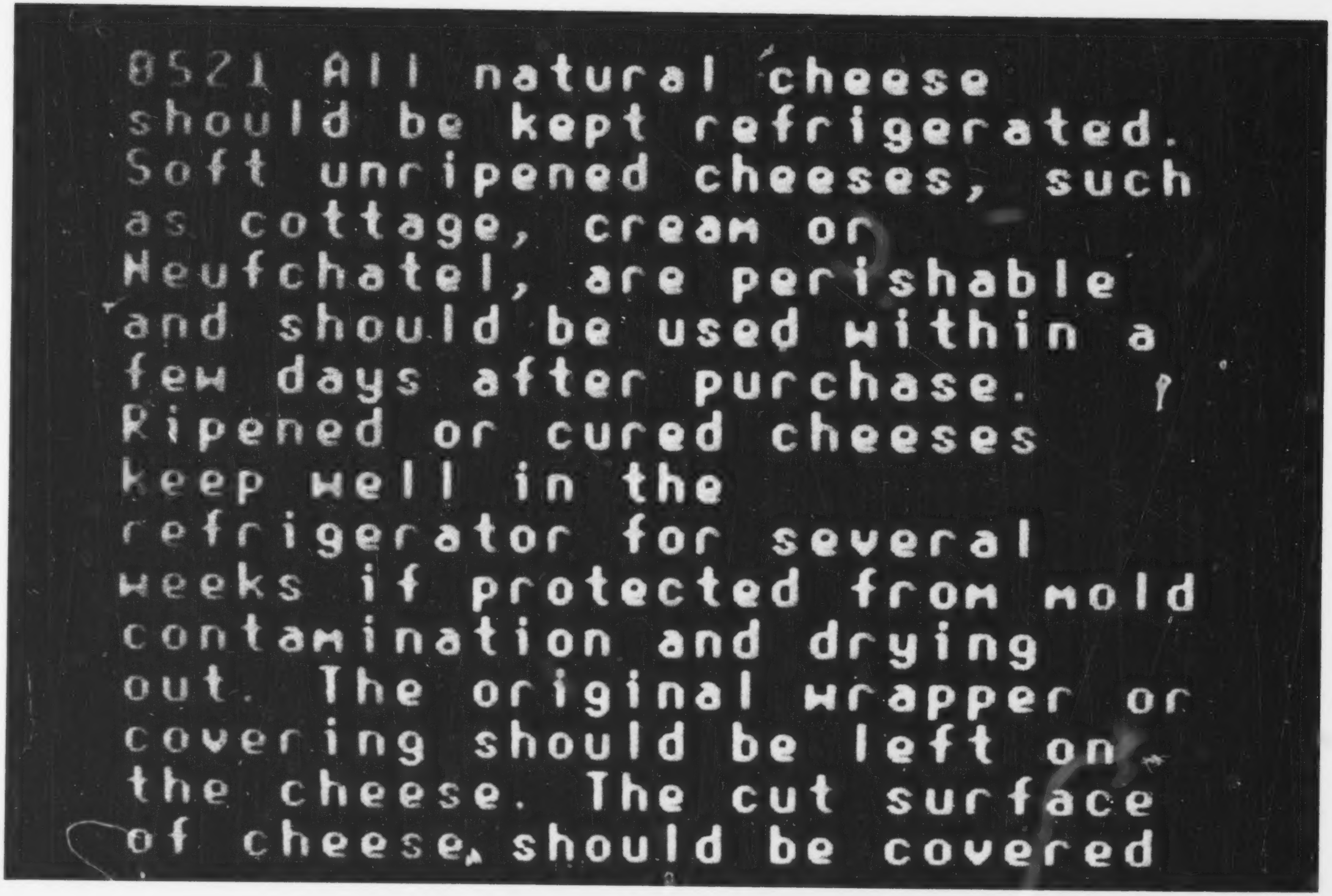


[illegible] demandes relatives
[illegible] renseignements sociaux
[illegible] rapidement. Par
[illegible] nous sommes
[illegible] compter de plus
[illegible] la bonne volonté
[illegible] interrogées
[illegible] fournir des
renseignements. Les
statistiques nationales dans
[illegible] domaines de la
croissance démographique, de
l'emploi, des dépenses des
consommateurs, pour n'en
nommer que quelques-uns,
doivent être continuellement



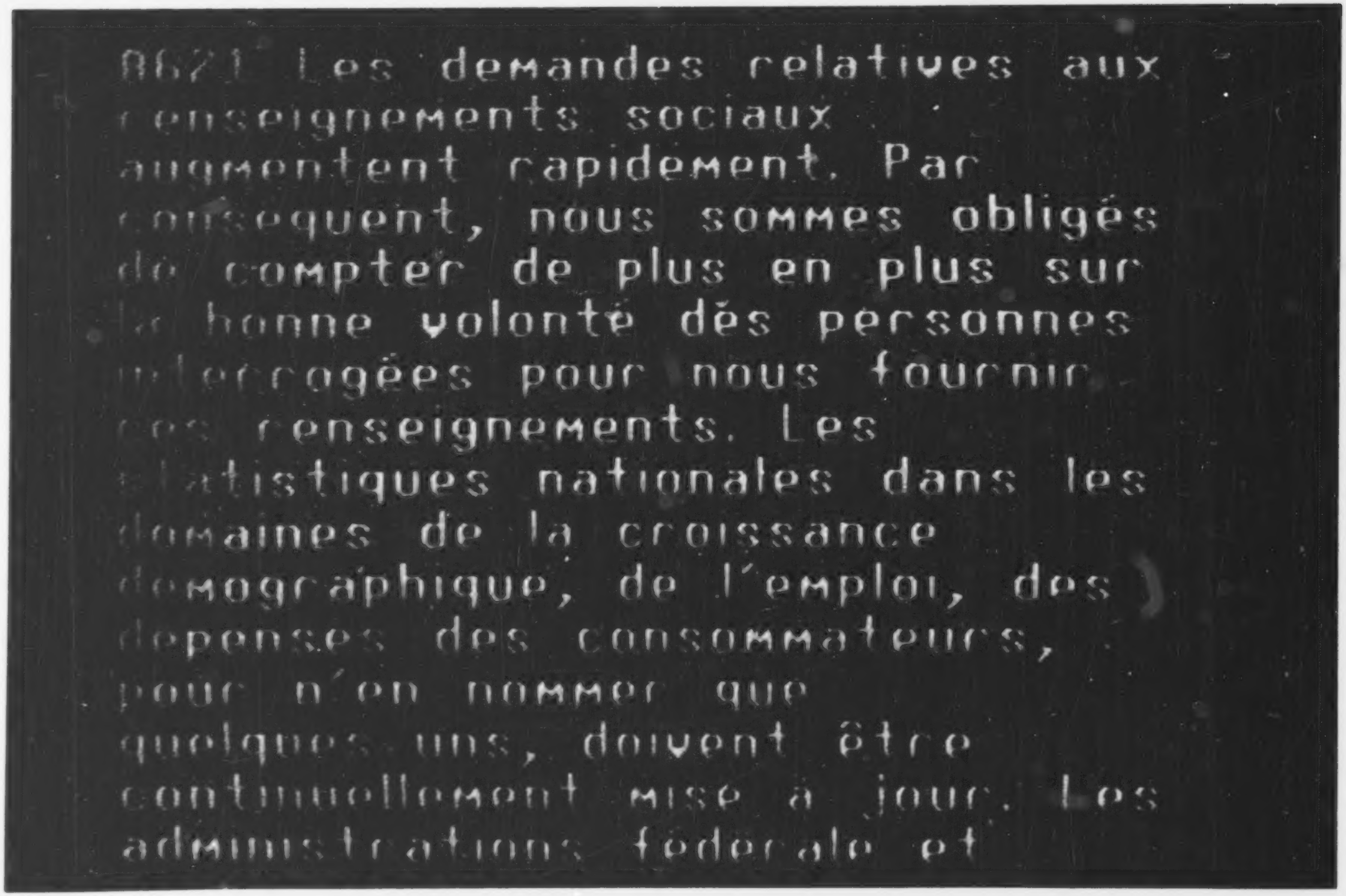
0521 All natural cheese should be kept refrigerated. Soft unripened cheeses, such as cottage, cream or Neufchatel, are perishable and should be used within a few days after purchase. Ripened or cured cheeses keep well in the refrigerator for several weeks if protected from mold contamination and drying out. The original wrapper or covering should be left on the cheese. The cut surface of cheese should be covered with wax paper, foil, or plastic wrapping

CHSET 5 (21) - RGB



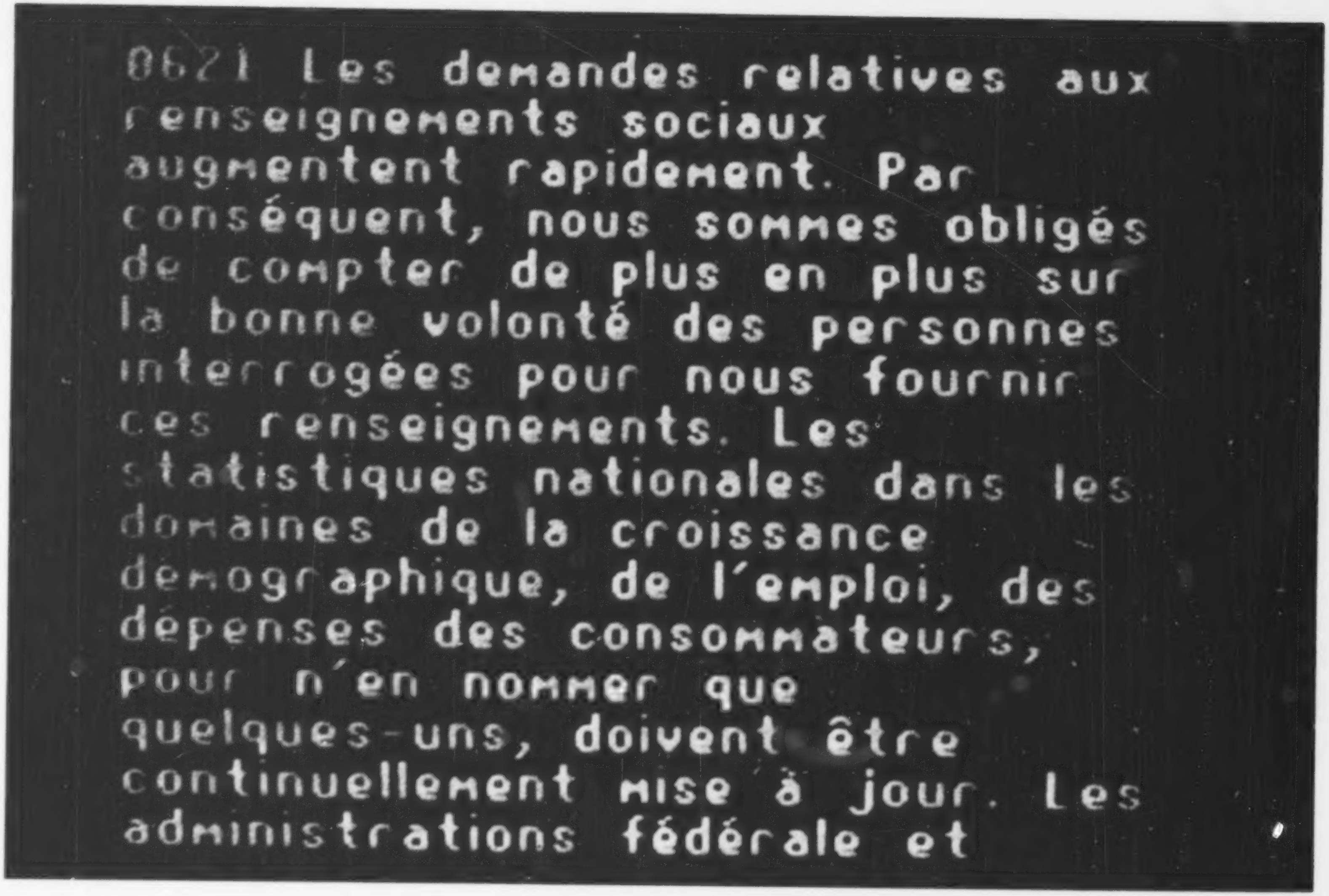
0521 All natural cheese
should be kept refrigerated.
Soft unripened cheeses, such
as cottage, cream or
Neufchatel, are perishable
and should be used within a
few days after purchase.
Ripened or cured cheeses
keep well in the
refrigerator for several
weeks if protected from mold
contamination and drying
out. The original wrapper or
covering should be left on
the cheese. The cut surface
of cheese should be covered

CHSET 5 (21) - CV



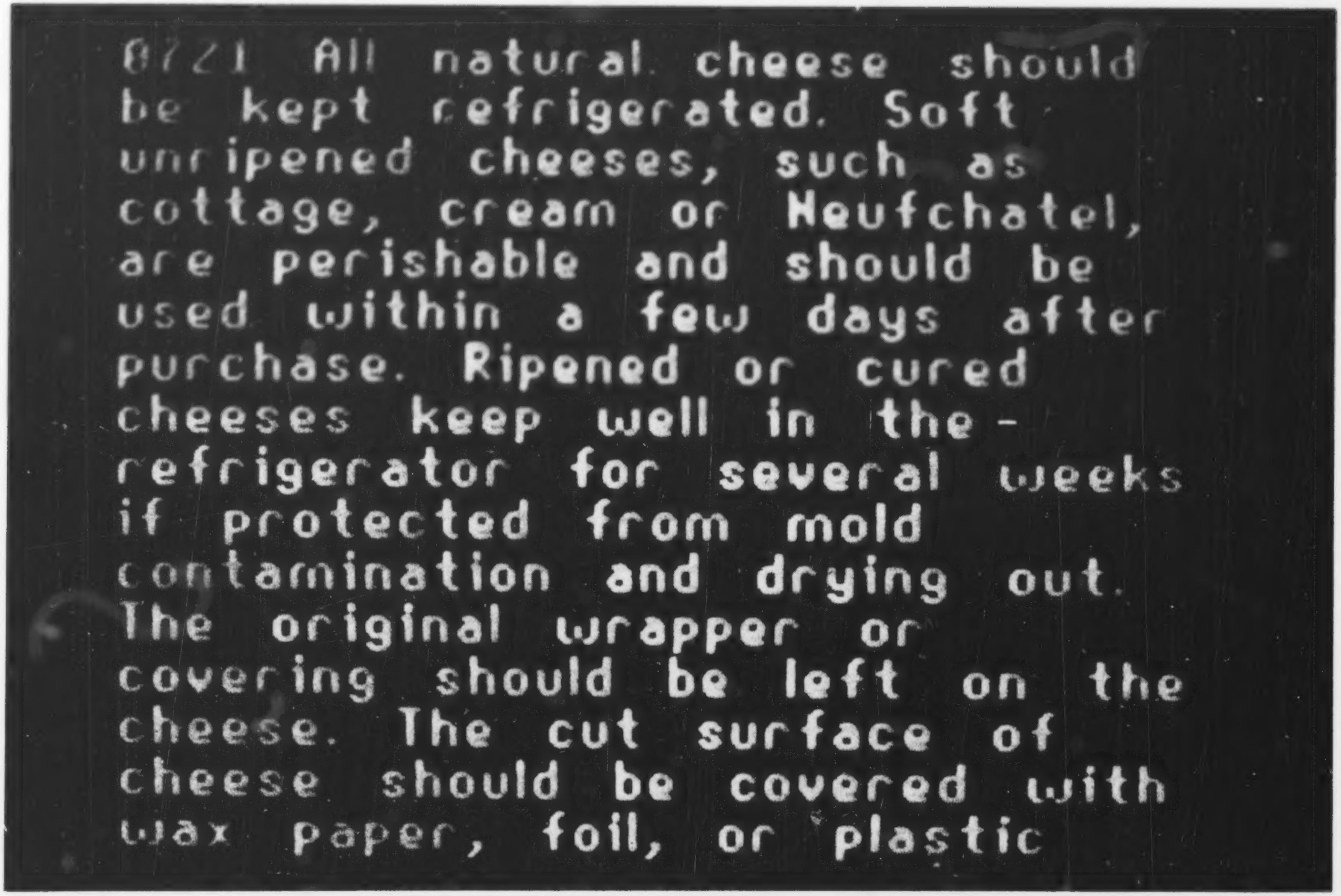
8621 Les demandes relatives aux
renseignements sociaux
augmentent rapidement. Par
consequent, nous sommes obligés
de compter de plus en plus sur
la bonne volonté dês personnes
interrogées pour nous fournir
ces renseignements. Les
statistiques nationales dans les
domaines de la croissance
demographique, de l'emploi, des
depenses des consommateurs,
pour n'en nommer que
quelques uns, doivent être
continuellement mise à jour. Les
administrations federale et

CHSET 6 (21) - RGB



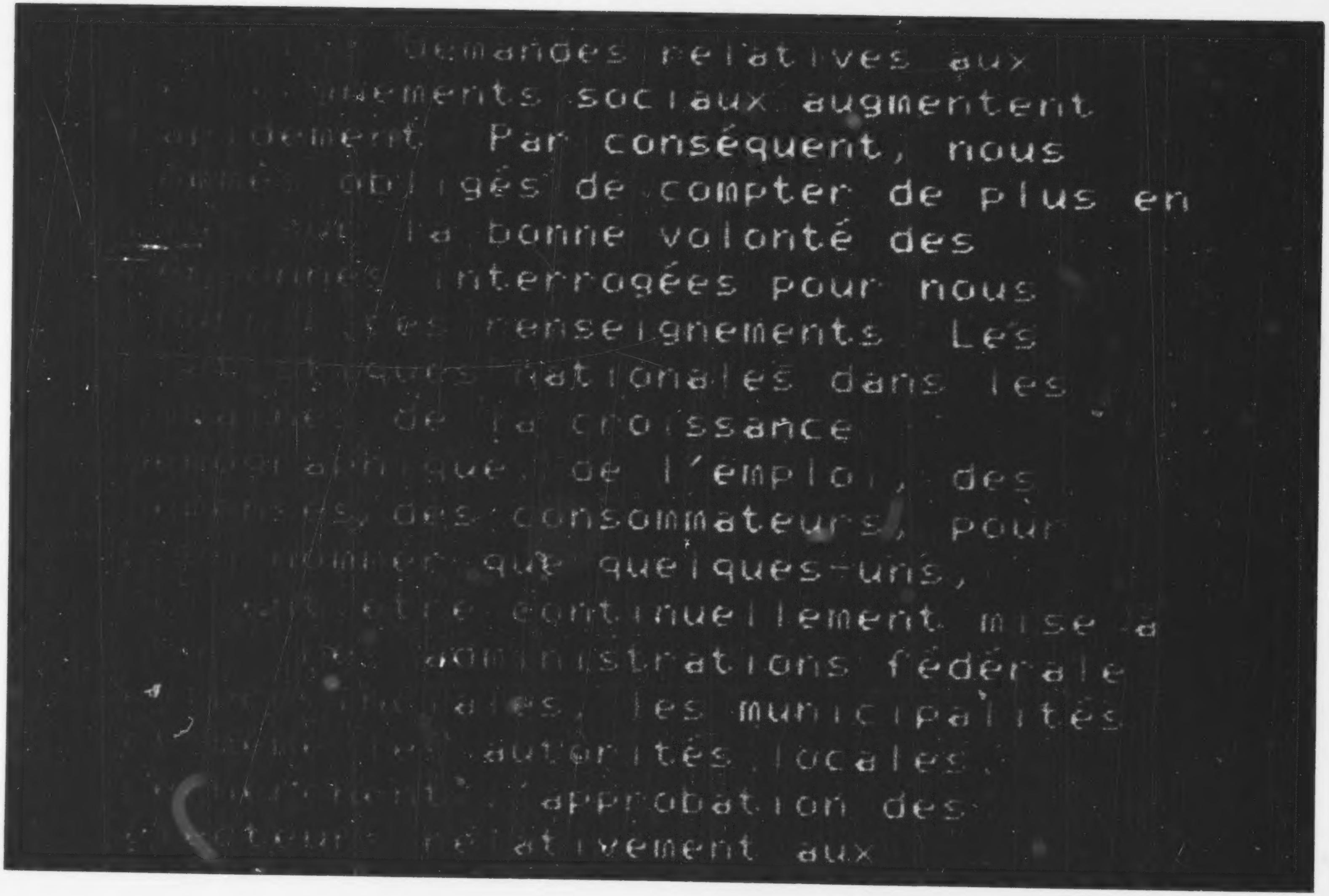
0621 Les demandes relatives aux renseignements sociaux augmentent rapidement. Par conséquent, nous sommes obligés de compter de plus en plus sur la bonne volonté des personnes interrogées pour nous fournir ces renseignements. Les statistiques nationales dans les domaines de la croissance démographique, de l'emploi, des dépenses des consommateurs, pour n'en nommer que quelques-uns, doivent être continuellement mise à jour. Les administrations fédérale et

CHSET 6 (21) - CV



0721 All natural cheese should
be kept refrigerated. Soft
unripened cheeses, such as
cottage, cream or Neufchatel,
are perishable and should be
used within a few days after
purchase. Ripened or cured
cheeses keep well in the -
refrigerator for several weeks
if protected from mold
contamination and drying out.
The original wrapper or
covering should be left on the
cheese. The cut surface of
cheese should be covered with
wax paper, foil, or plastic

CHSET 7 (21) - CV

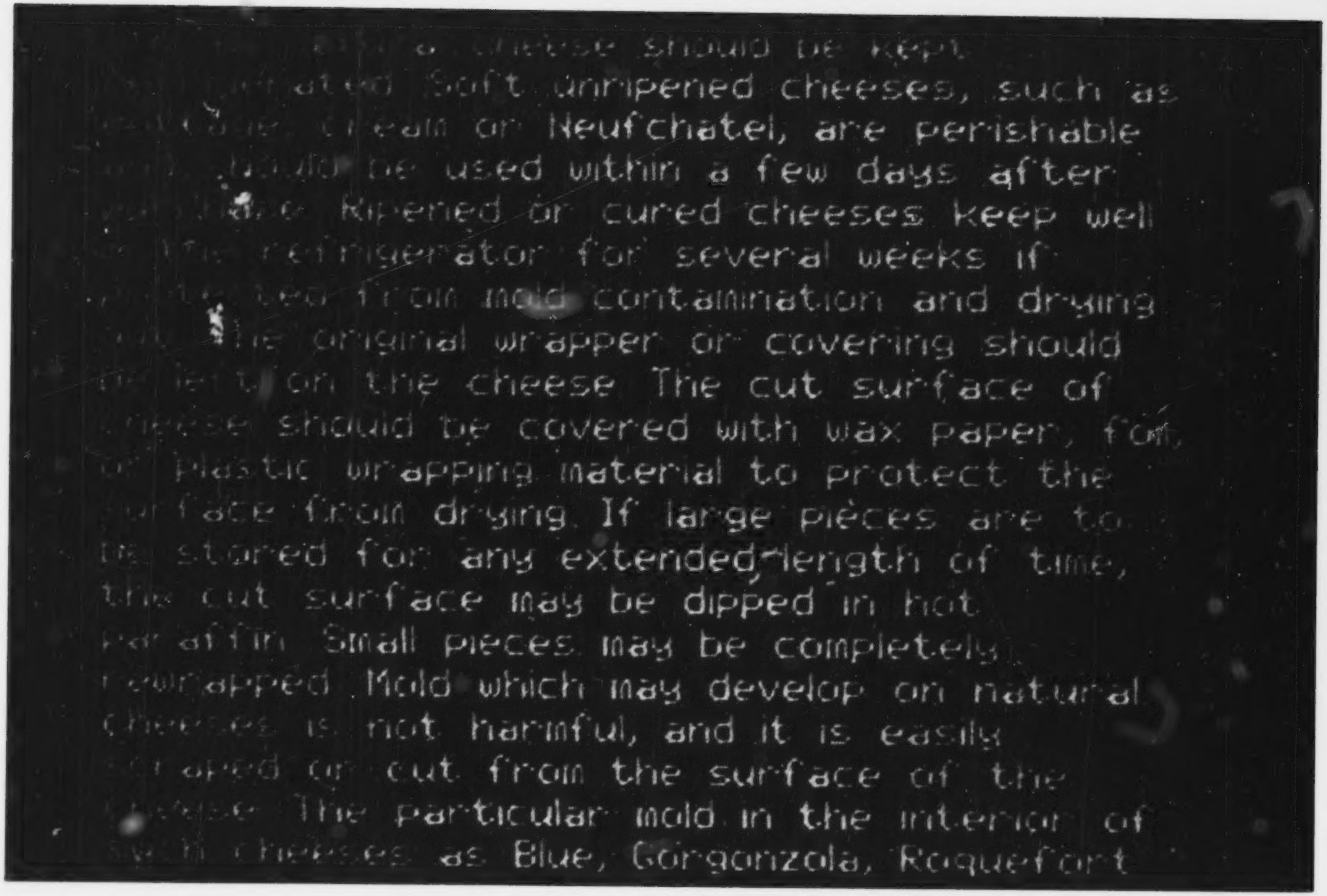


[illegible] demandes relatives aux
renseignements sociaux augmentent
rapidement. Par conséquent, nous
sommes obligés de compter de plus en
plus sur la bonne volonté des
personnes interrogées pour nous
fournir les renseignements. Les
statistiques nationales dans les
domaines de la croissance
démographique, de l'emploi, des
dépenses des consommateurs, pour
ne nommer que quelques-uns,
doit être continuellement mise à
[illegible] administrations fédérale
provinciales, les municipalités
[illegible] autorités locales.
[illegible] l'approbation des
électeurs relativement aux

CHSET 8 (22) - RGB

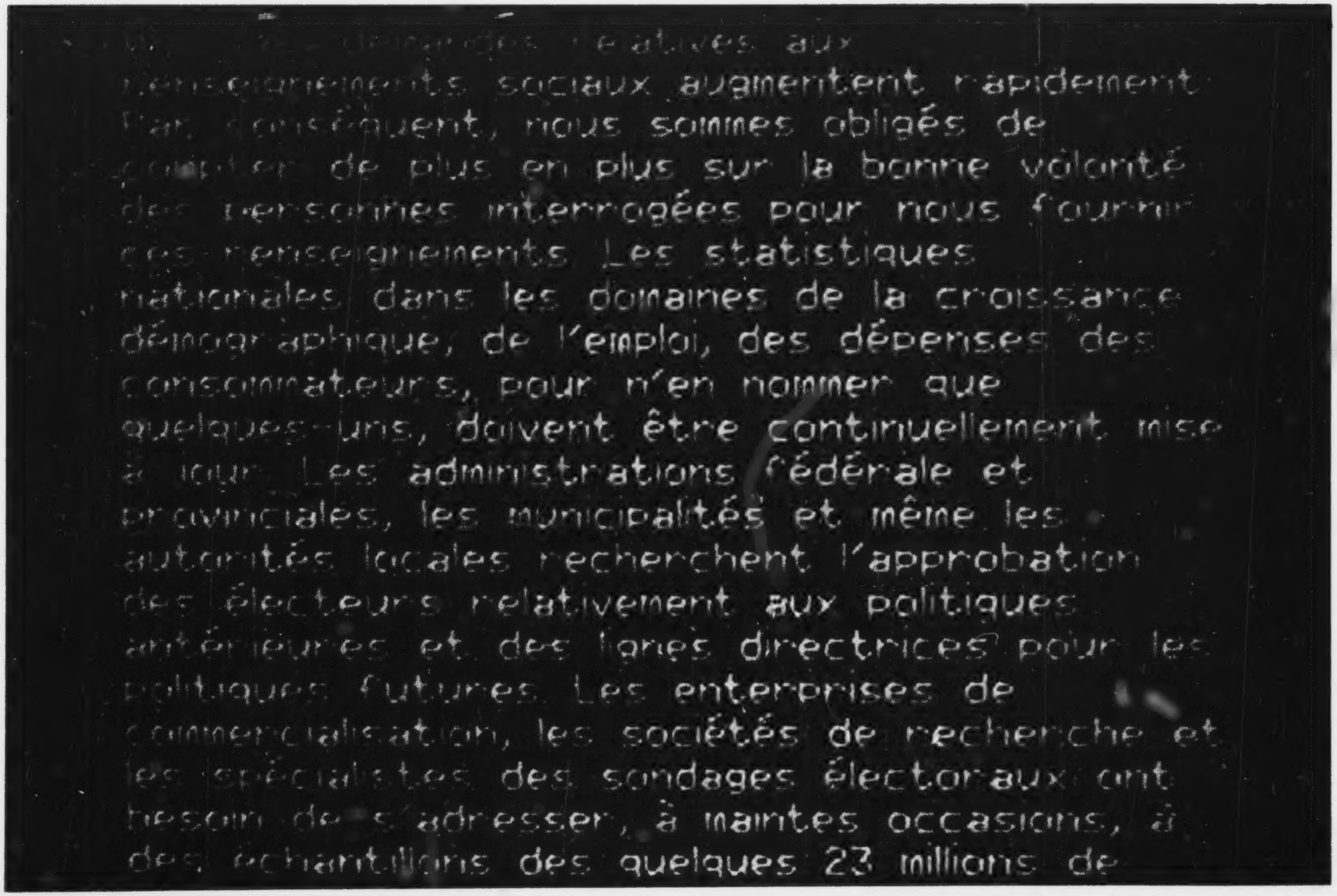
APPENDIX B

The figures in this appendix show the appearance of text using the character sets and spacings recommended for the field trials. The spacings permit display of 20 lines of 40 characters per line, or 16 lines with 32 characters per line. Legends are as described in Appendix A.



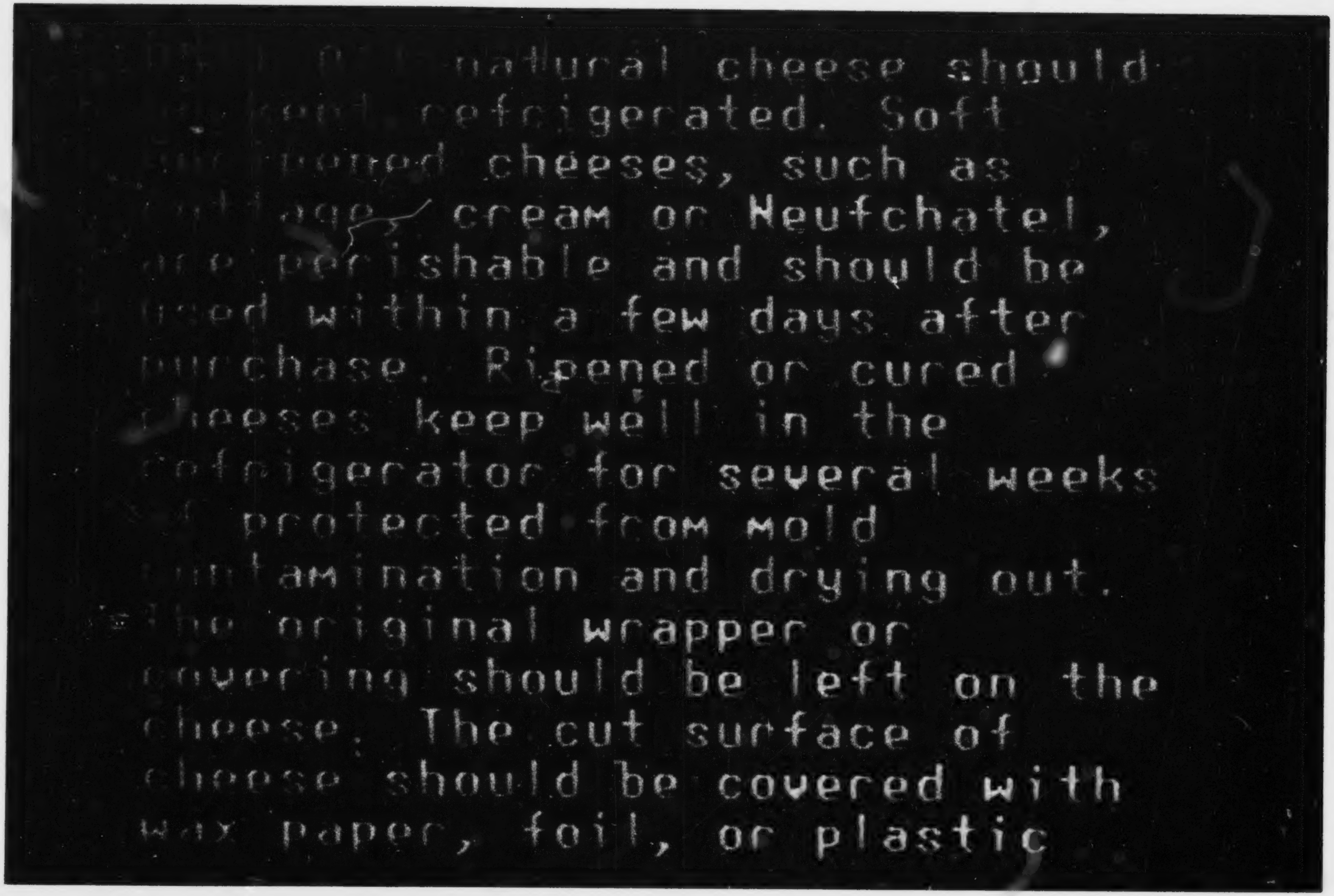
[illegible] a cheese should be kept. refrigerated. Soft unripened cheeses, such as cottage, cream or Neufchatel, are perishable and should be used within a few days after purchase. Ripened or cured cheeses keep well in the refrigerator for several weeks if protected from mold contamination and drying. The original wrapper or covering should be left on the cheese. The cut surface of cheese should be covered with wax paper, foil, or plastic wrapping material to protect the surface from drying. If large pieces are to be stored for any extended length of time, the cut surface may be dipped in hot paraffin. Small pieces may be completely rewrapped. Mold which may develop on natural cheeses is not harmful, and it is easily scraped or cut from the surface of the cheese. The particular mold in the interior of such cheeses as Blue, Gorgonzola, Roquefort

CHSET 1 (12) - RGB



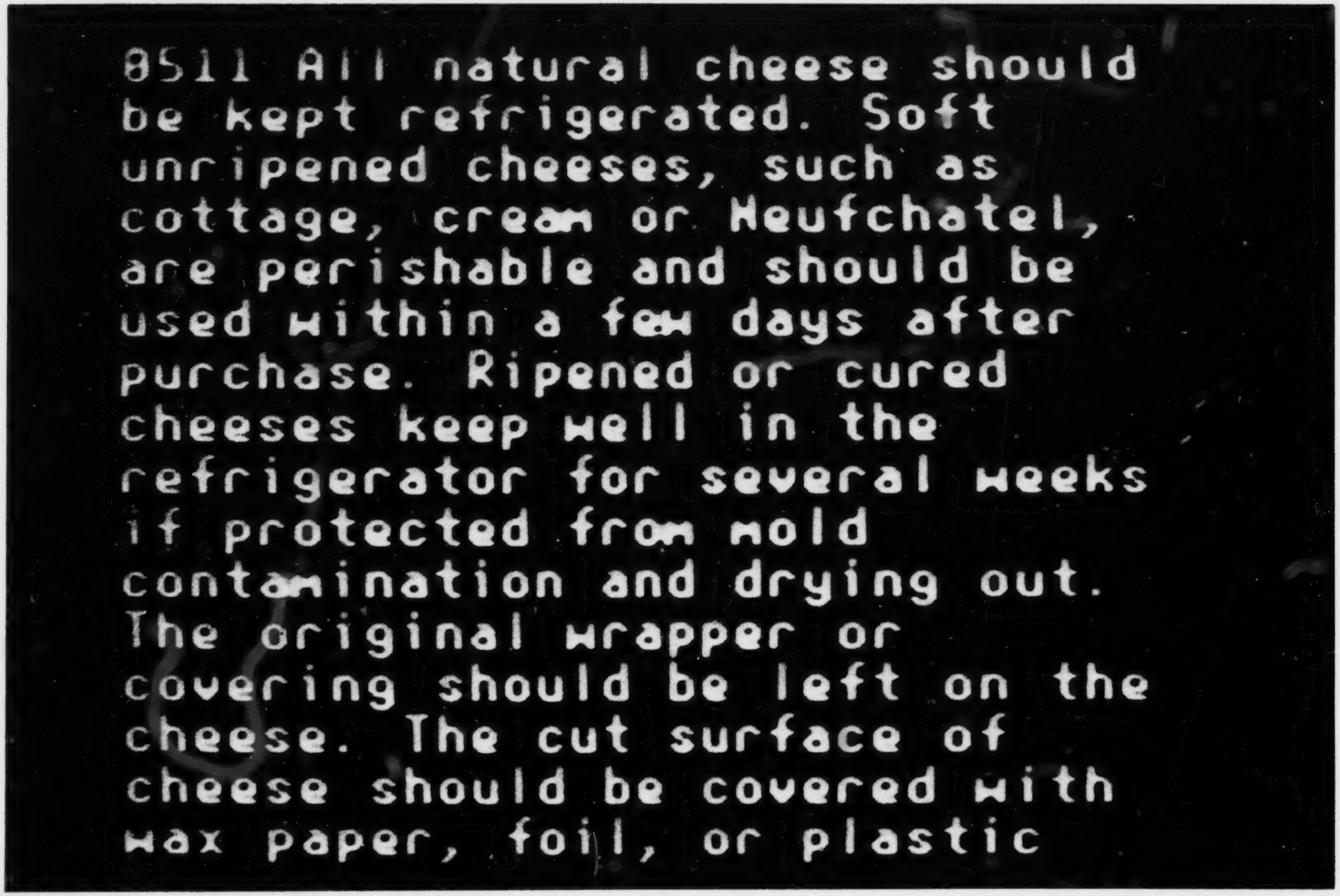
[illegible] demandes relatives aux renseignements sociaux augmentent rapidement. Par conséquent, nous sommes obligés de compter de plus en plus sur la bonne volonté des personnes interrogées pour nous fournir ces renseignements. Les statistiques nationales dans les domaines de la croissance démographique, de l'emploi, des dépenses des consommateurs, pour n'en nommer que quelques-uns, doivent être continuellement mise à jour. Les administrations fédérale et provinciales, les municipalités et même les autorités locales recherchent l'approbation des électeurs relativement aux politiques antérieures et des lignes directrices pour les politiques futures. Les enterprises de commercialisation, les sociétés de recherche et les spécialistes des sondages électoraux ont besoin de s'adresser, à maintes occasions, à des échantillons des quelques 23 millions de

CHSET 8 (11) - RGB



All natural cheese should
be kept refrigerated. Soft
unripened cheeses, such as
cottage, cream or Neufchatel,
are perishable and should be
used within a few days after
purchase. Ripened or cured
cheeses keep well in the
refrigerator for several weeks
if protected from mold
contamination and drying out.
The original wrapper or
covering should be left on the
cheese. The cut surface of
cheese should be covered with
wax paper, foil, or plastic

CHSET 5 (11) - RGB



8511 All natural cheese should
be kept refrigerated. Soft
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purchase. Ripened or cured
cheeses keep well in the
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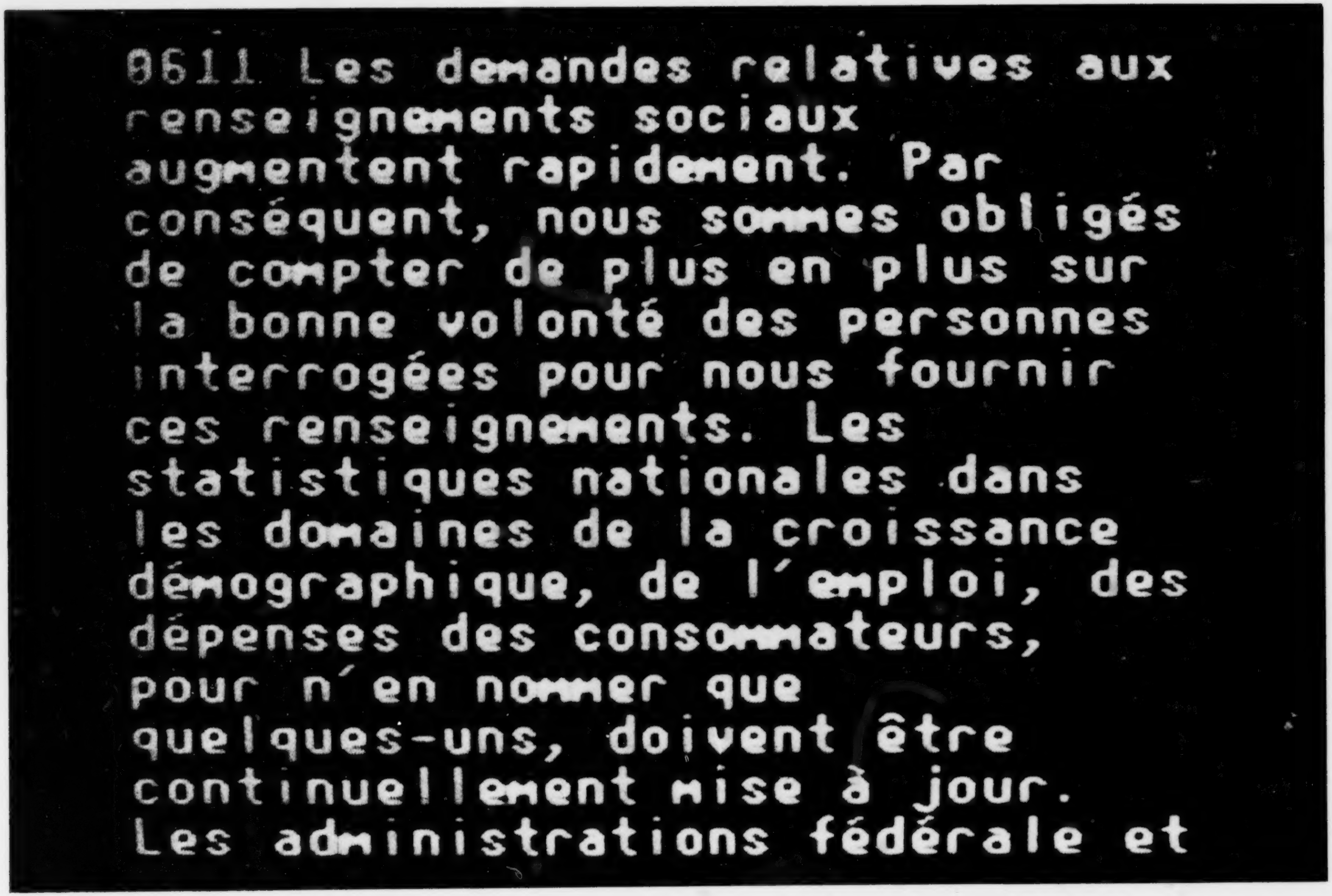
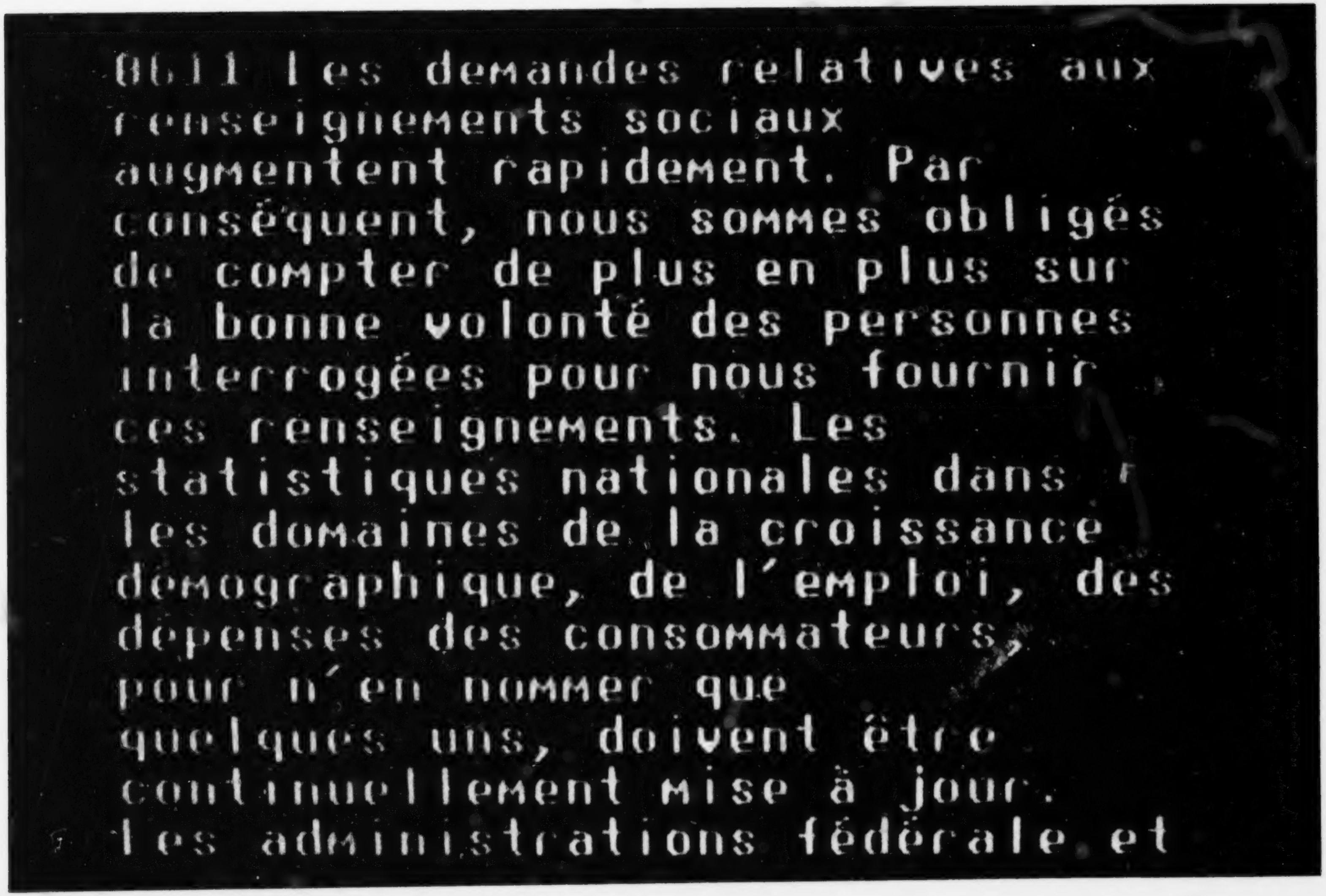
contamination and drying out.
The original wrapper or
covering should be left on the
cheese. The cut surface of
cheese should be covered with
wax paper, foil, or plastic

CHSET 5 (11) - CV



0611 Les demandes relatives aux renseignements sociaux augmentent rapidement. Par conséquent, nous sommes obligés de compter de plus en plus sur la bonne volonté des personnes interrogées pour nous fournir ces renseignements. Les statistiques nationales dans les domaines de la croissance démographique, de l'emploi, des dépenses des consommateurs, pour n'en nommer que quelques-uns, doivent être continuellement mise à jour. Les administrations fédérale et

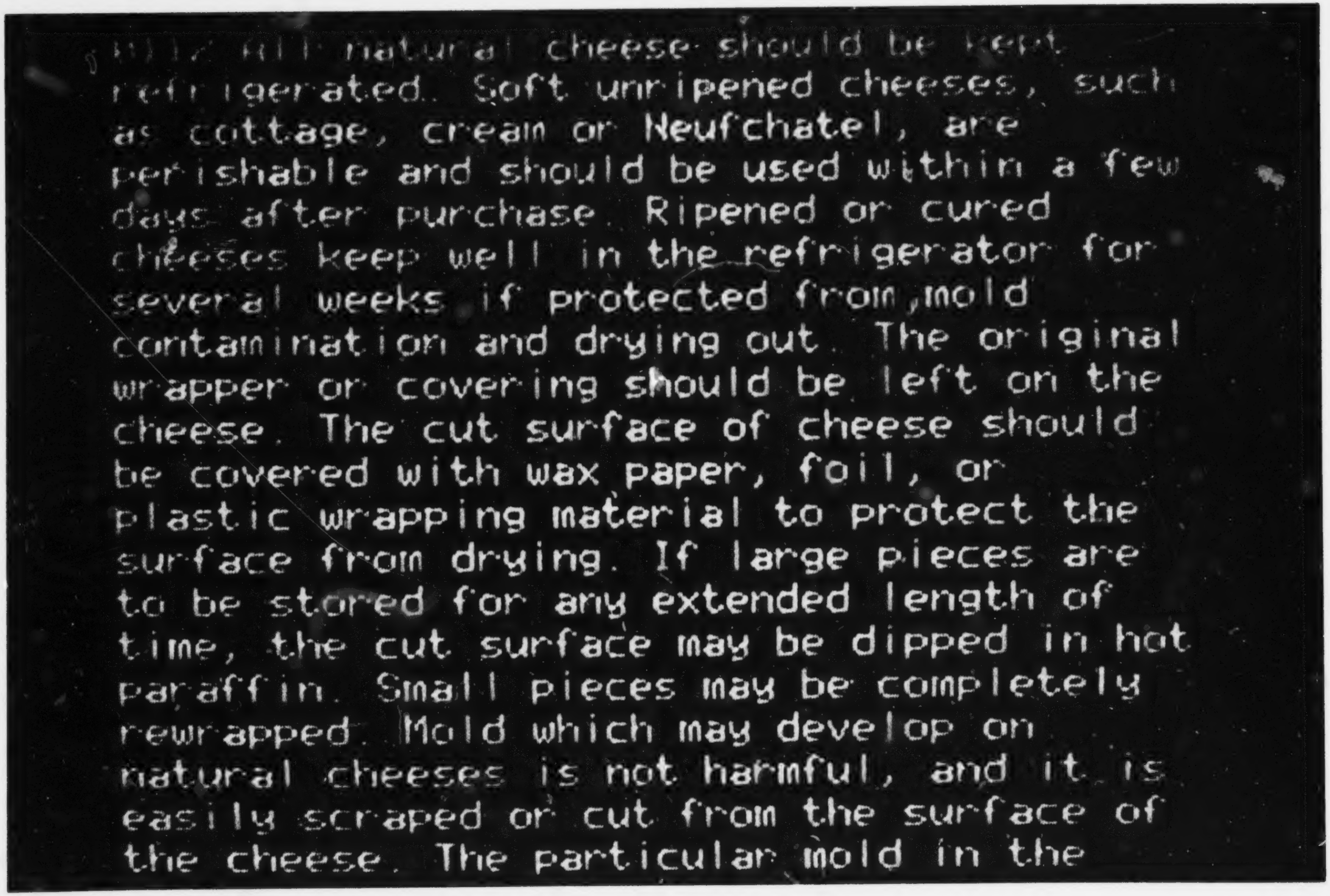


0611 les demandes relatives aux renseignements sociaux augmentent rapidement. Par conséquent, nous sommes obligés de compter de plus en plus sur la bonne volonté des personnes interrogées pour nous fournir ces renseignements. Les statistiques nationales dans les domaines de la croissance démographique, de l'emploi, des depenses des consommateurs, pour n'en nommer que quelques uns, doivent être continuellement mise à jour. les administrations fédérale et

CHSET 6 (11) - RGB

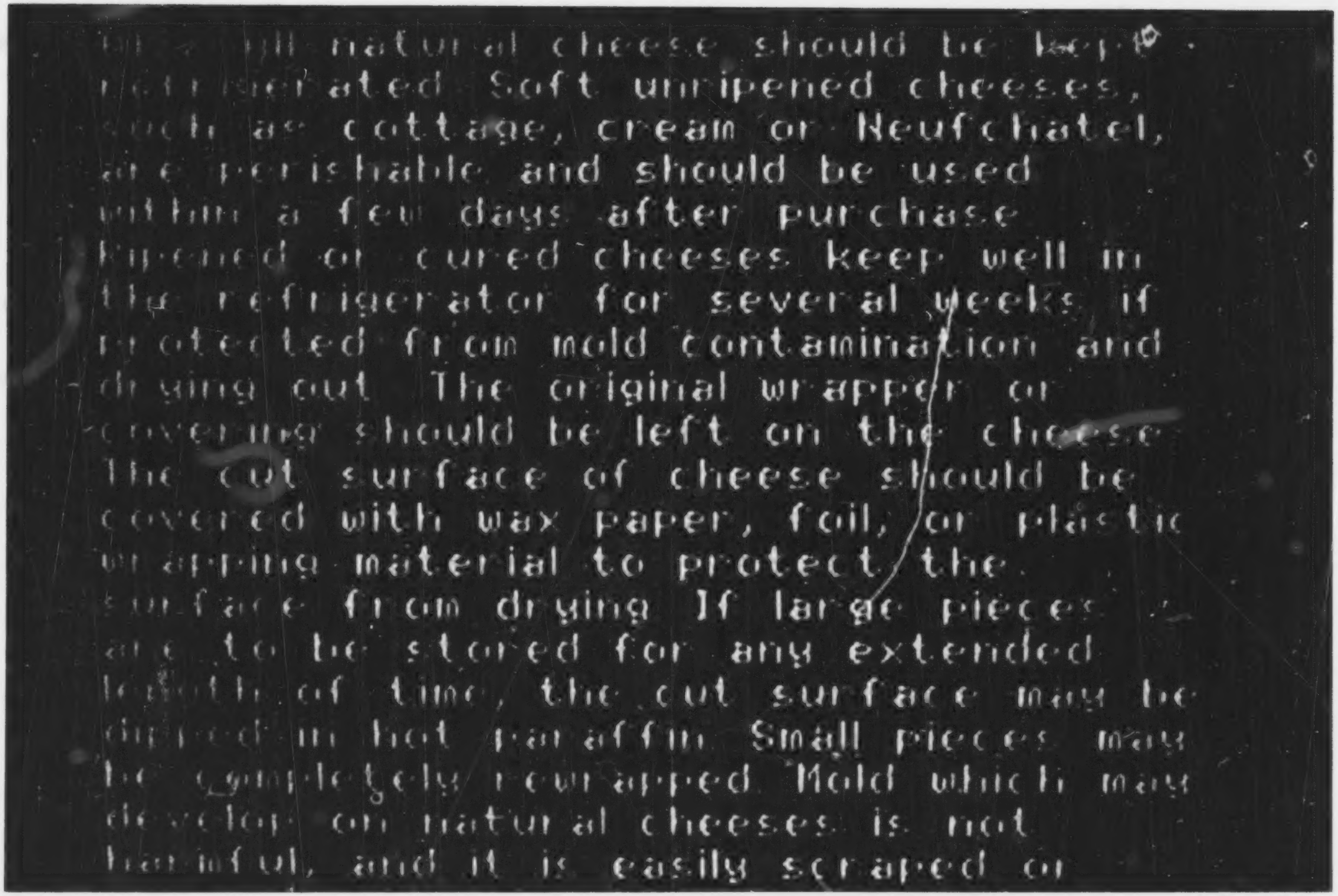
APPENDIX C

The figures in this appendix show the effect of proportional spacing on the readability of text. The beneficial effect of increasing the horizontal spacing by one pixel is also shown. Again, the legends are as described in Appendix A.



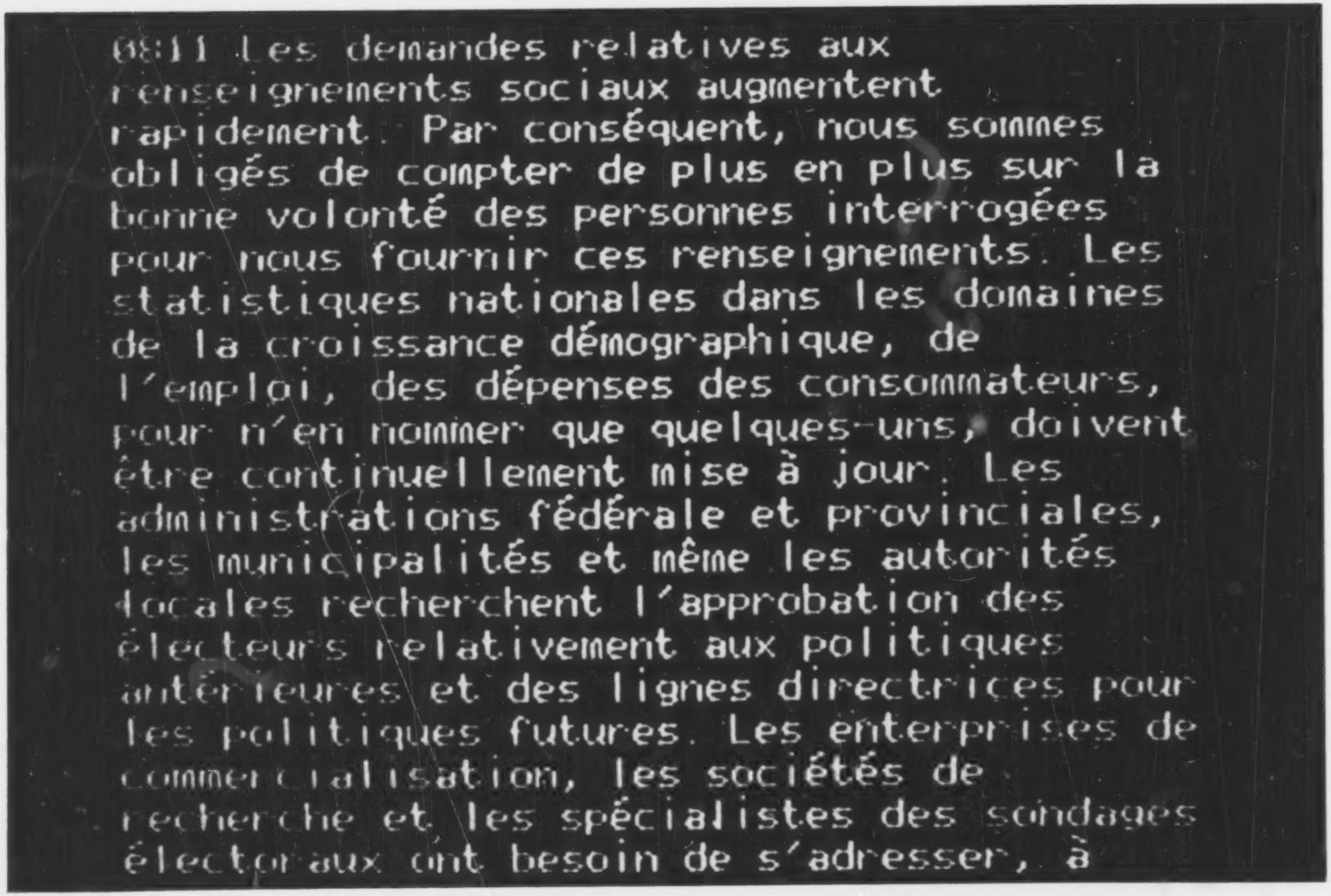
[illegible] All natural cheese should be kept refrigerated. Soft unripened cheeses, such as cottage, cream or Neufchatel, are perishable and should be used within a few days after purchase. Ripened or cured cheeses keep well in the refrigerator for several weeks if protected from mold contamination and drying out. The original wrapper or covering should be left on the cheese. The cut surface of cheese should be covered with wax paper, foil, or plastic wrapping material to protect the surface from drying. If large pieces are to be stored for any extended length of time, the cut surface may be dipped in hot paraffin. Small pieces may be completely rewrapped. Mold which may develop on natural cheeses is not harmful, and it is easily scraped or cut from the surface of the cheese. The particular mold in the

CHSET 1 (12) - RGB



[illegible] all natural cheese should be kept refrigerated. Soft unripened cheeses, such as cottage, cream or Neufchatel, are perishable and should be used within a few days after purchase. Ripened or cured cheeses keep well in the refrigerator for several weeks if protected from mold contamination and drying out. The original wrapper or covering should be left on the cheese. The cut surface of cheese should be covered with wax paper, foil, or plastic wrapping material to protect the surface from drying. If large pieces are to be stored for any extended length of time, the cut surface may be dipped in hot paraffin. Small pieces may be completely rewrapped. Mold which may develop on natural cheeses is not harmful, and it is easily scraped or

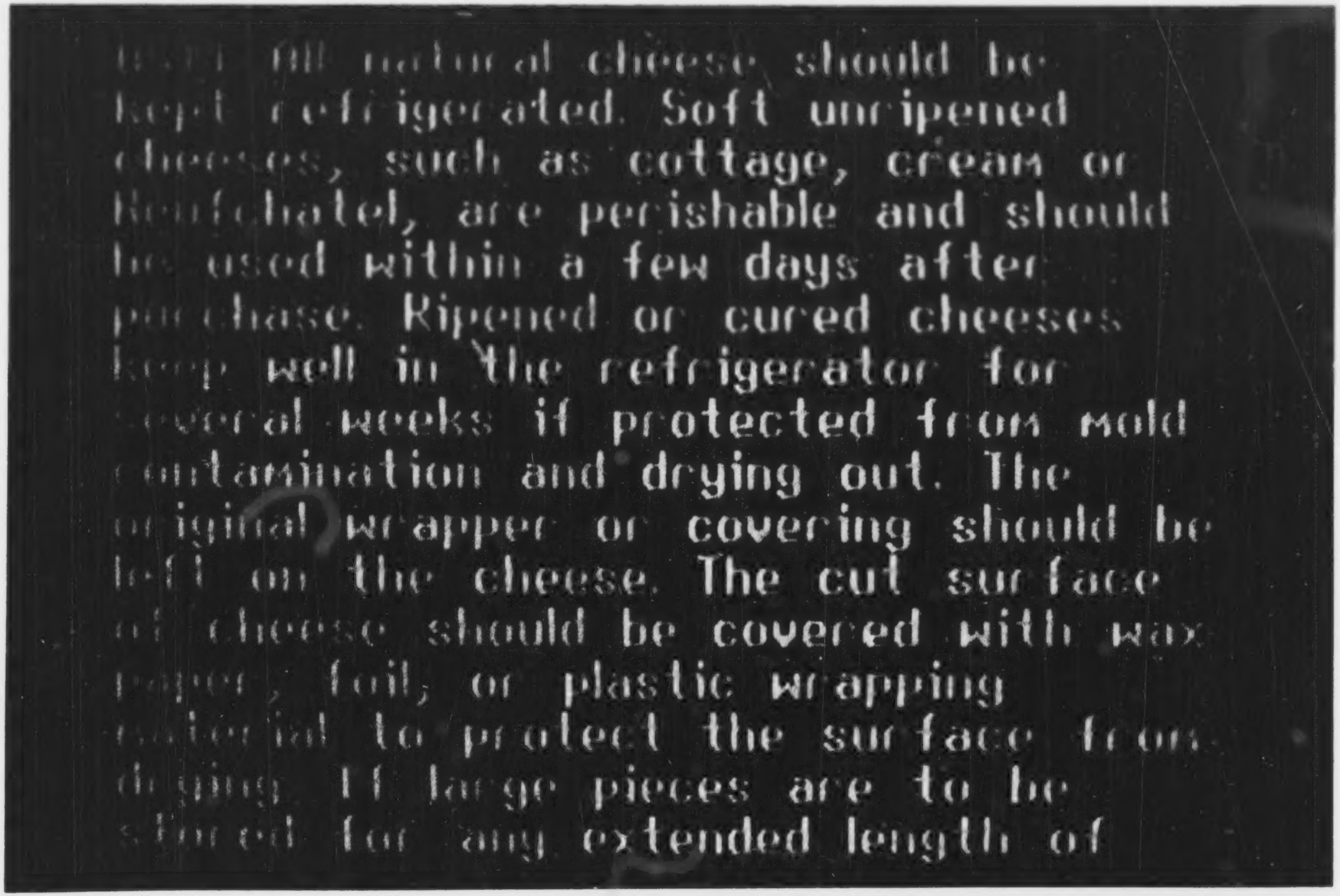
CHSET 1 (22) - RGB



08:11 Les demandes relatives aux renseignements sociaux augmentent rapidement. Par conséquent, nous sommes obligés de compter de plus en plus sur la bonne volonté des personnes interrogées pour nous fournir ces renseignements. Les statistiques nationales dans les domaines de la croissance démographique, de l'emploi, des dépenses des consommateurs, pour n'en nommer que quelques-uns, doivent être continuellement mise à jour. Les administrations fédérale et provinciales, les municipalités et même les autorités locales recherchent l'approbation des électeurs relativement aux politiques antérieures et des lignes directrices pour les politiques futures. Les enterprises de commercialisation, les sociétés de recherche et les spécialistes des sondages électoraux ont besoin de s'adresser, à

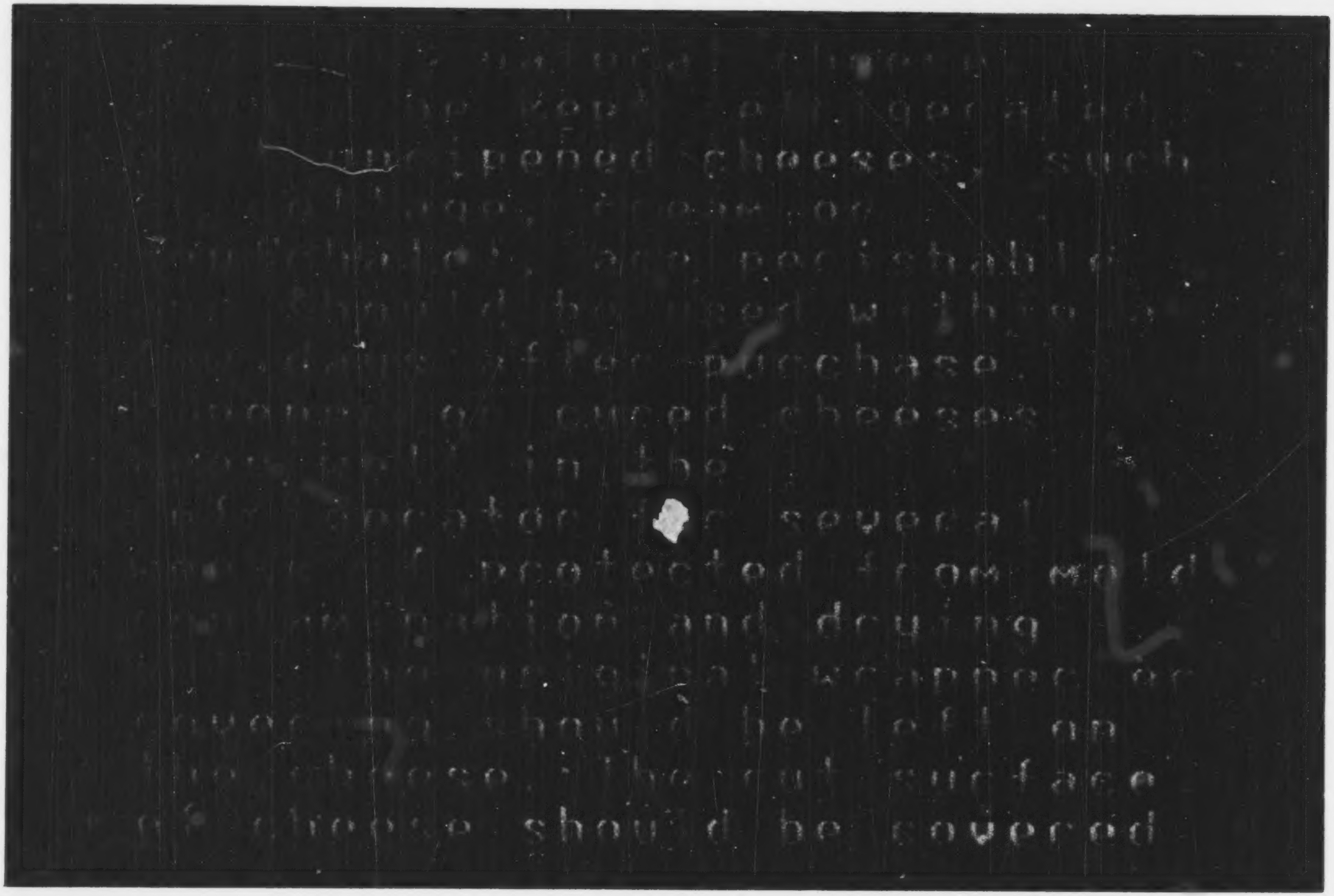
CHSET 8 (11) - RGB

CHSET 8 (21) - RGB



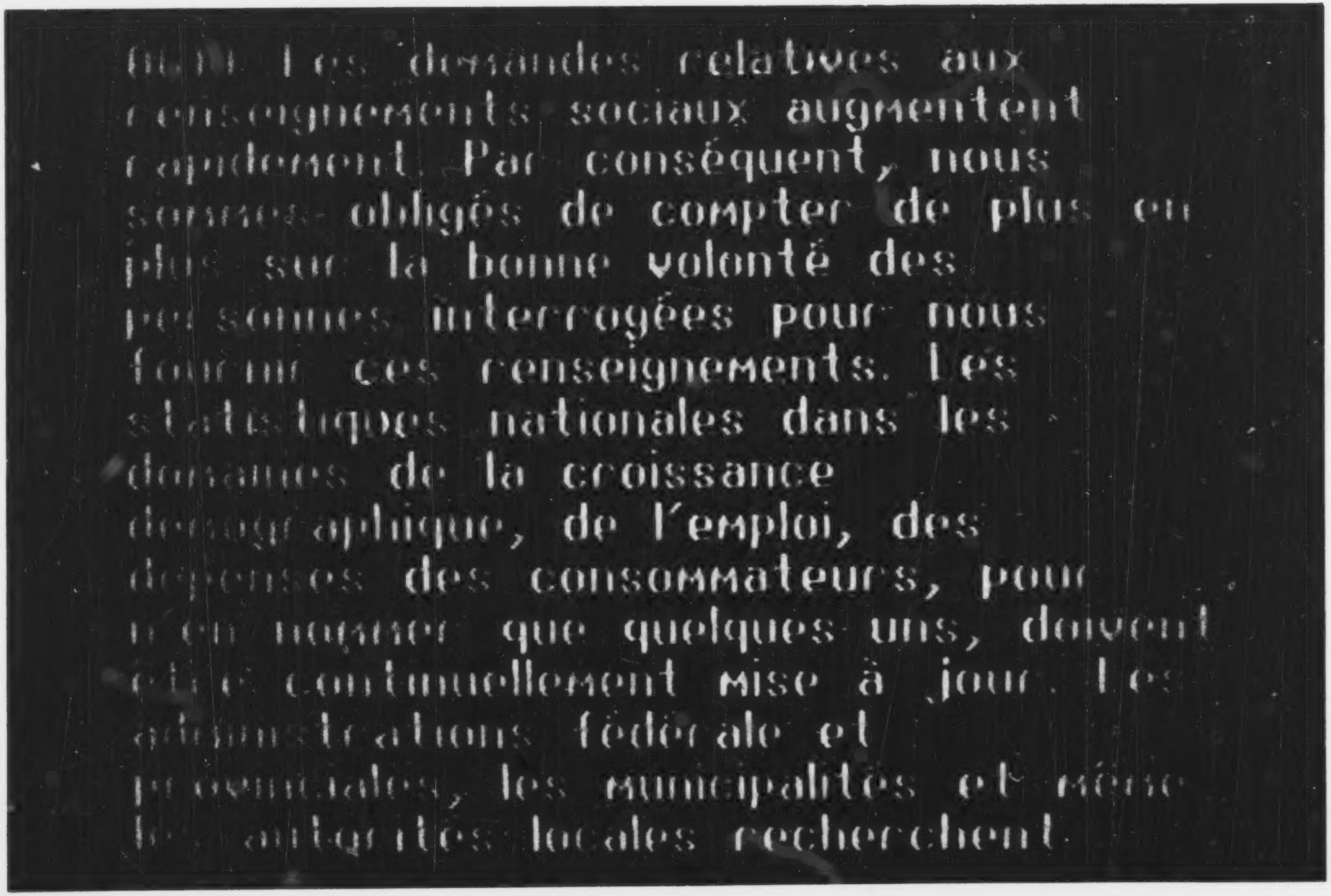
[illegible] All natural cheese should be kept refrigerated. Soft unripened cheeses, such as cottage, cream or Neufchatel, are perishable and should be used within a few days after purchase. Ripened or cured cheeses keep well in the refrigerator for several weeks if protected from mold contamination and drying out. The original wrapper or covering should be left on the cheese. The cut surface of cheese should be covered with wax paper, foil, or plastic wrapping material to protect the surface from drying. If large pieces are to be stored for any extended length of

CHSET 5 (11) - RGB



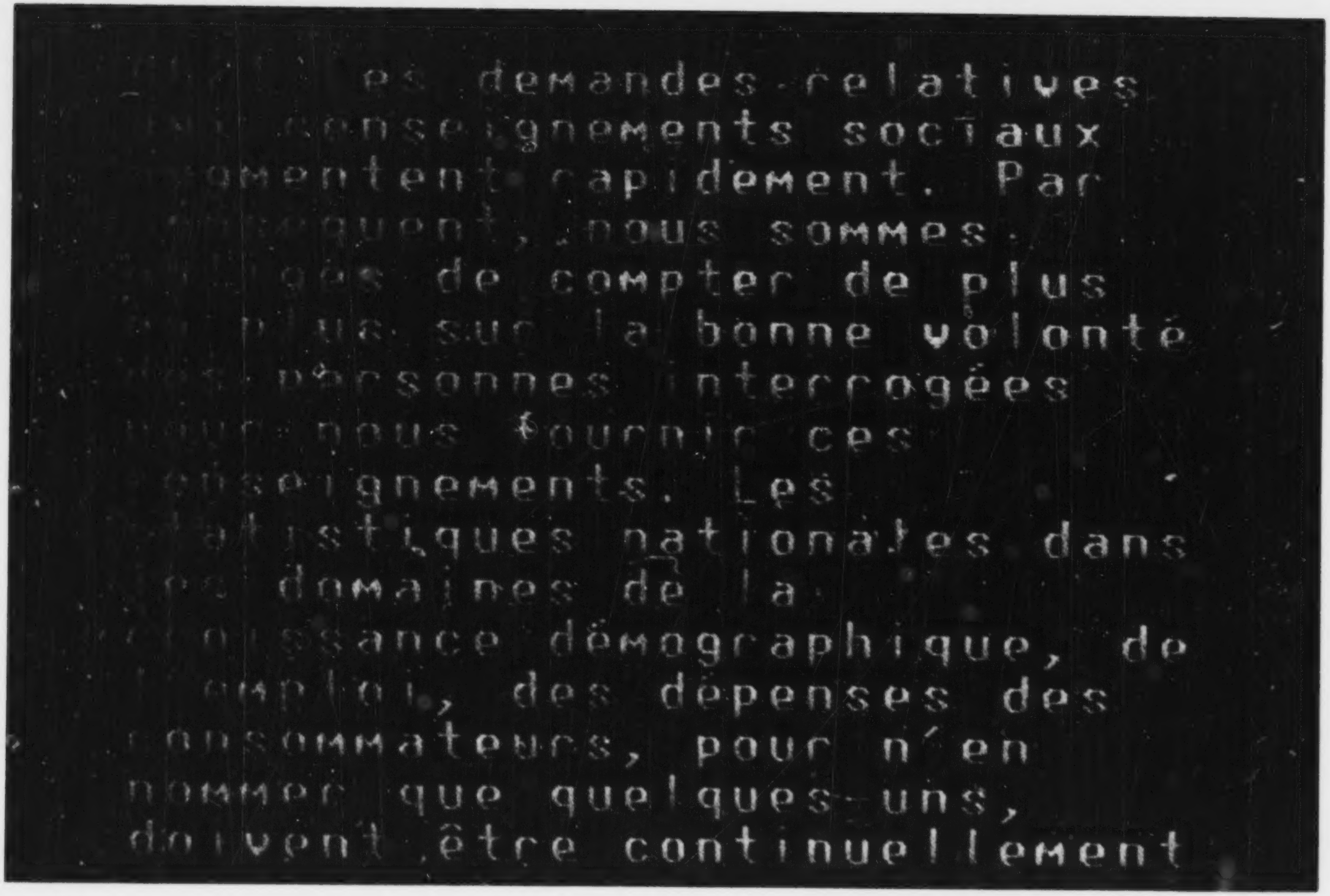
[illegible] natural cheese [illegible]
be kept refrigerated.
Unripened cheeses, such
as cottage, cream or
Neufchatel, are perishable
and should be used within a
days after purchase.
Ripened or cured cheeses
keep well in the
refrigerator for several
weeks if protected from mold
contamination and drying.
The original wrapper or
covering should be left on
the cheese. The cut surface
of cheese should be covered

CHSET 5 (21) - RGB



(ii) Les demandes relatives aux renseignements sociaux augmentent rapidement. Par conséquent, nous sommes obligés de compter de plus en plus sur la bonne volonté des personnes interrogées pour nous fournir ces renseignements. Les statistiques nationales dans les domaines de la croissance démographique, de l'emploi, des dépenses des consommateurs, pour n'en nommer que quelques uns, doivent être continuellement mise à jour. Les administrations fédérale et provinciales, les municipalités et même les autorités locales recherchent

CHSET 6 (11) - RGB



Les demandes relatives
aux renseignements sociaux
augmentent rapidement. Par
conséquent, nous sommes
obligés de compter de plus
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des personnes interrogées
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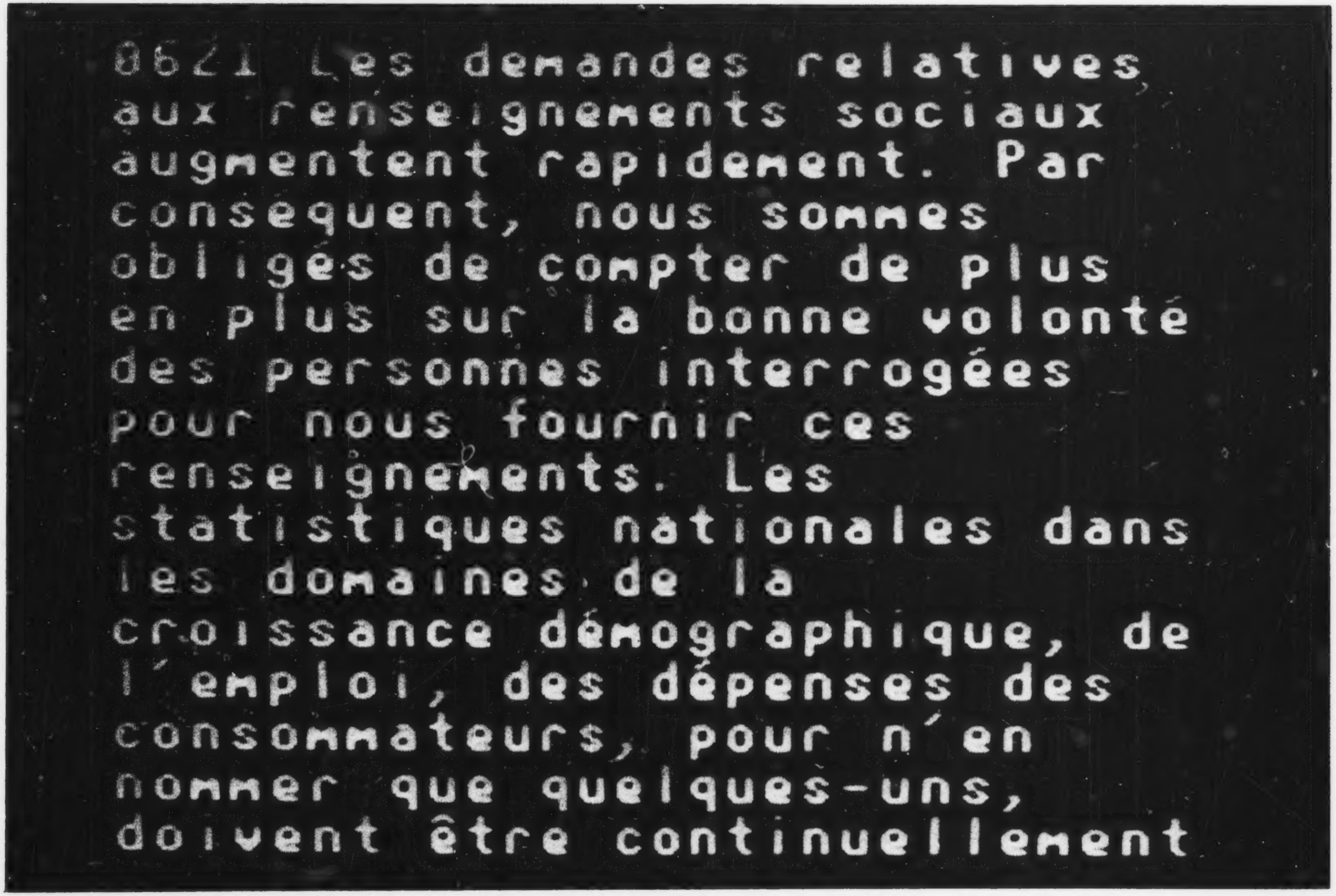
renseignements. Les
statistiques nationales dans
les domaines de la
croissance démographique, de
l'emploi, des dépenses des
consommateurs, pour n'en
nommer que quelques-uns,
doivent être continuellement

CHSET 6 (21) - RGB



0621 Les demandes relatives
aux renseignements sociaux
augmentent rapidement. Par
consequent, nous sommes
obligés de compter de plus
en plus sur la bonne volonté
des personnes interrogées
pour nous fournir ces
renseignements. Les
statistiques nationales dans
les domaines de la
croissance démographique, de
l´emploi, des dépenses des
consommateurs, pour n´en
nommer que quelques-uns,
doivent être continuellement

CHSET 6 (21) - CV

SPACING OF CHARACTERS ON A TELEVISION DISPLAY: 7 X 9 CHARACTER SET*

W. C. Treurniet

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*Data for this report was collected at the Human Factors Laboratory, Department of Communications, Ottawa, Canada.

Executive Summary

A previous experiment with a 5x7 character set determined that there should be no more than 40 characters per line on a Telidon page, and no more than 20 lines per page. Further, it was shown that characters with descenders should extend below the line by at least one pixel. This paper reports results of a similar experiment using a 7x9 character set.

The experiment indicated that descender characters should extend at least two pixels below the line, that characters on a line should be separated by three pixels, and that the space between lines can be as little as one pixel. These values increase the size of the basic 7x9 character matrix to a 10x12 matrix. Since the useable area on the television display has dimensions of approximately 216 by 288 pixels, the results indicate that no more than 18 lines with 28 characters per line should be displayed on Telidon using this character set.

Twenty-eight character spaces permit only about five words to be displayed on one line. When hyphenation is not allowed, a longer word can result in undesirable large gaps at the ends of lines. Implementation of "proportional spacing" appears to reduce this effect, but further research is needed to confirm this impression. Proportional spacing is the reduction of the character matrix width for narrow letters such as "i" or "l". If proportional spacing is technically not feasible on Telidon, it may be desirable to employ a horizontal spacing of two pixels. The resulting 9x12 character matrix would permit 32 characters per line.

An earlier paper entitled "Spacing of Characters on a Television Display" used a letter search task to arrive at recommendations on spacing of characters on a television display. For the 5x7 character set used in that study, the best horizontal spacing was found to be two pixels, and the best spacing between lines of letters was found to be three pixels. Further, the experiment also showed that descender characters should extend below the line by at least one pixel. This paper reports the results of a similar experiment using the 7x9 character set presently used on Telidon.

An Electrohome Model C40 19 inch colour television set modified for RGB input was employed in the experiment. This television is similar in quality to domestic television sets, and has rectangular phosphor elements. Letters were displayed in white on a colourless background.

The methodology employed was identical to that described in the earlier paper. A page of randomly chosen, lower case rows of letters was displayed on each trial. The critical line to which the subject was required to attend was marked in the left margin by a "plus" symbol. Because the length of the descender on the letters "g", "j", "p", "q" and "y" was a variable of interest, these five letters were selected as the search targets. The first letter in the critical line was always one of these five letters and indicated to the subject at the beginning of each trial which letter was the target. The subject's task was to immediately scan the critical line for the next occurrance of the target letter. When that letter was located, the subject was asked to say the immediately following letter. The subject was further requested to scan the line only once. If the end of the line was reached without identifying the target letter, the subject was requested to give the end letter as his response. The target letter occurred only once on the critical line following the initial cue, and the two indicated response letters were also unique in that line. The subject was further instructed to attempt to regulate his scanning rate so that targets were missed on about 10 percent of the trials. Display onset was relatively instantaneous and activation of a voice switch by the response resulted in erasure of the display. Response time was measured to the nearest msec and the actual response was entered at a computer console by the experimenter during the three second inter-trial interval.

The subject was seated approximately four feet from the display without a head restrainer. A page was displayed to facilitate explanation of the task by the experimenter, and then 10 trials were presented for practice. The experiment itself was a 3x3x3 within design with length of descender, horizontal spacing and vertical spacing as the three factors. Length of descender refers to the amount of protrusion below the line by descender characters and was 0, 1 or 2 pixels. Both vertical and horizontal spacings were 1, 2 or 3 pixels. Therefore, the total design consisted of 27 cells. Each of the five target letters was presented twice in each experimental condition. The 27 conditions were randomly ordered within each of 10 blocks of trials. Thus, the total number of trials for each of 11 subjects was 270. Because the session lasted about 35 minutes, a short pause was permitted following the 135th trial.

A repeated measures analysis of variance was performed on each of three dependent variables: (1) frequency of misses, (2) scanning rate in characters/sec, and (3) scanning rate in pixels/sec. Analysis of frequency of misses showed a significant effect due to horizontal spacing ($F(2,20)=3.595$, $p<.05$), and an effect due to length of descender ($F(2,20)=29.378$, $p<.01$). No interactions were significant. Analysis of scanning rate in characters/sec showed that the effect of vertical spacing just missed the criterion for significance ($F(2,20)=3.311$, $p<.10$). However, there was a significant effect due to horizontal spacing (F(2,20)=30.208, p<.01) and length of descender (F(2,20)=16.514, p<.01). No interactions were significant. Analysis of scanning rate in pixels/sec showed a significant effect due to horizontal spacing (F(2,20)=77.701, p<.01), and length of descender (F(2,20)=16.361, p<.01). Figures 1 and 2 show the means corresponding to the above effects. Table 1 shows the proportion of the total variance explained by each of the significant effects.

Table 1

Percentage of Total Variance Explained

	Variable		
	Miss Frequency	Character per sec	Pixels per sec
Horizontal Spacing	2.5	4.5	9.8
Descender Length	16.1	3.2	3.2

The statistical significance of differences among the means was tested using the Newman-Keuls procedure (Winer, 1962). The frequency of misses decreased significantly with each increase in length of descender. Further, scanning rate in characters or pixels per second increased significantly with each increase in descender length. These

FIGURE I

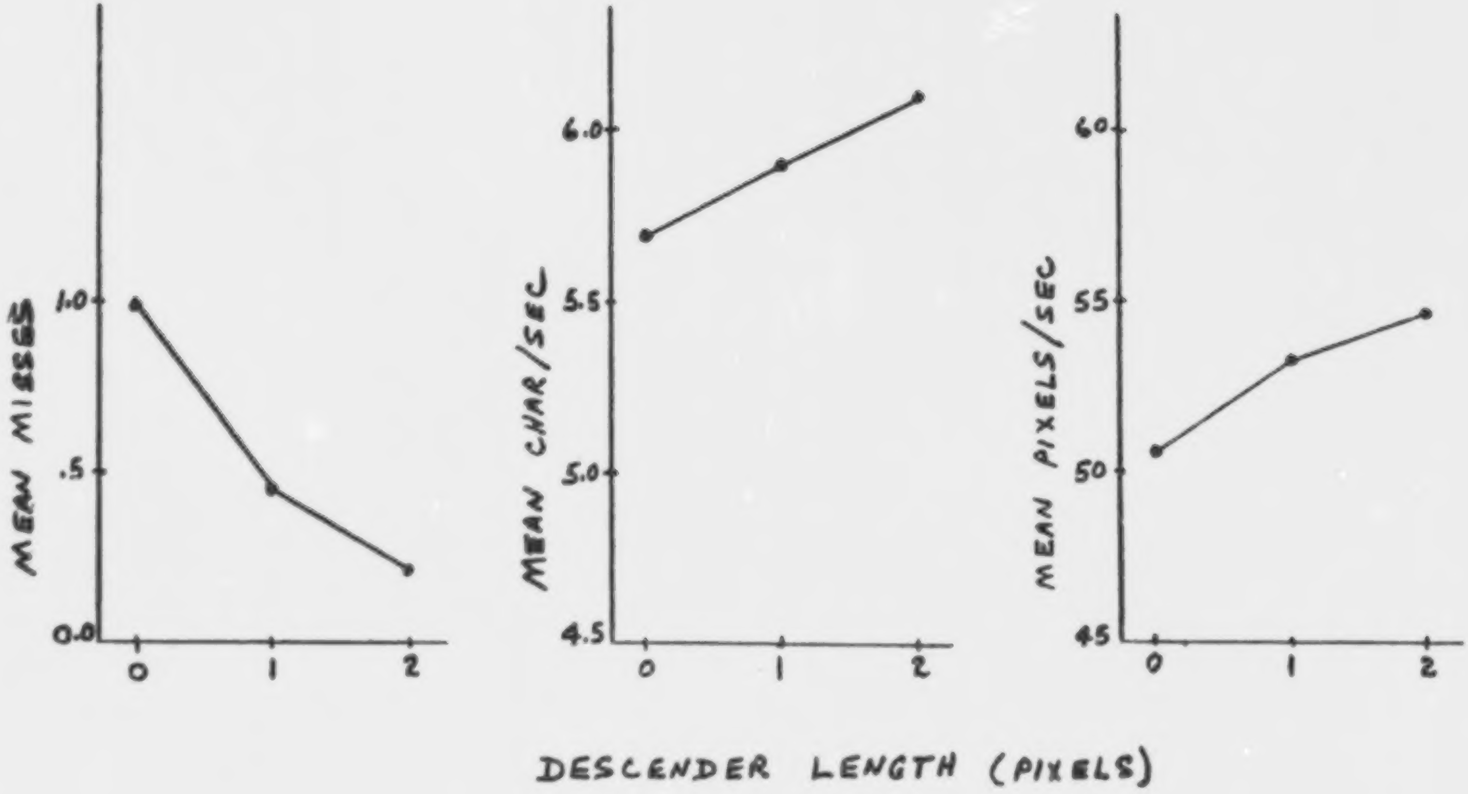
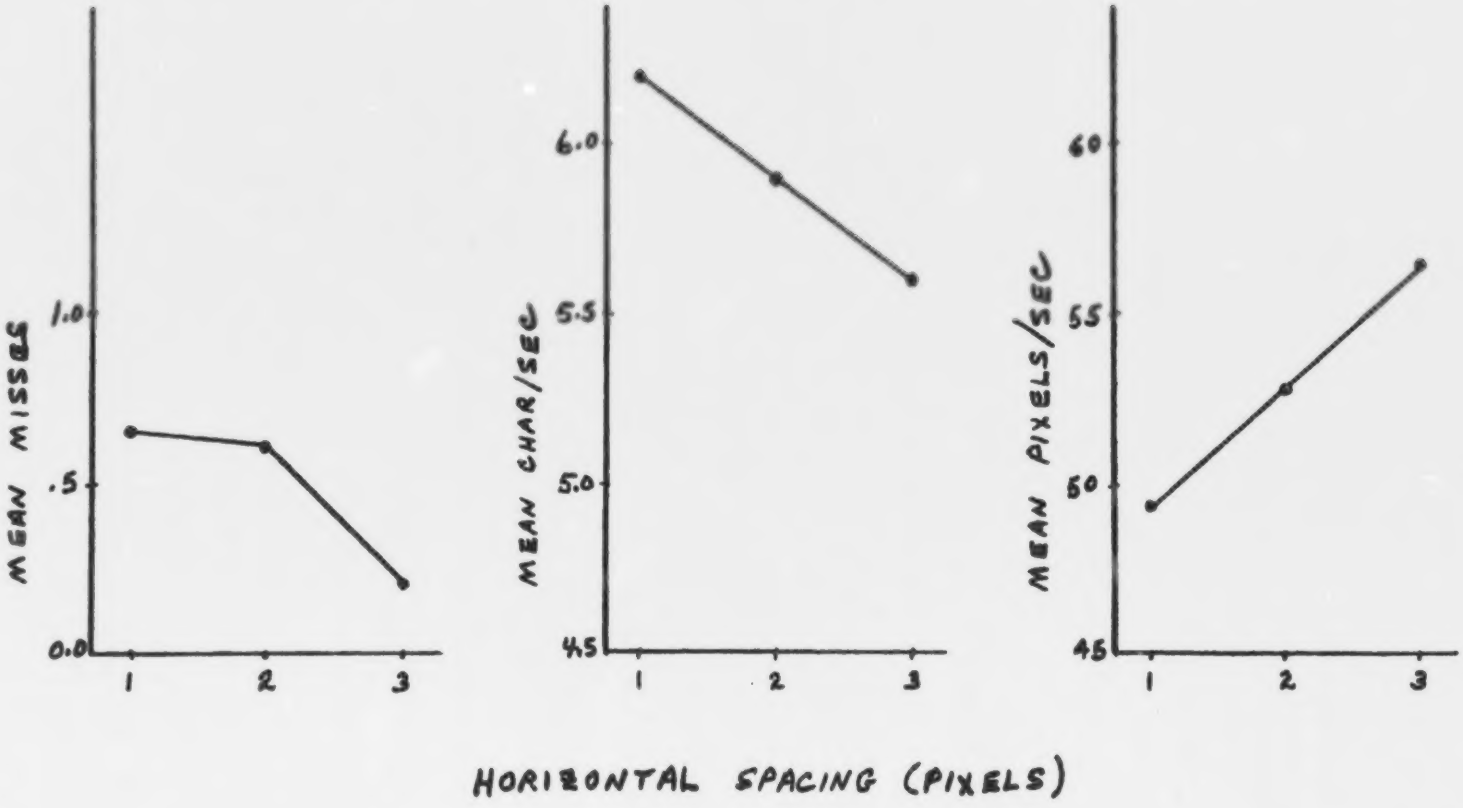

MEAN MISSES
1.0
.5
0.0
MEAN CHAR/SEC
6.0
5.5
5.0
4.5
MEAN PIXELS/SEC
60
55
50
45
0
1
2
DESCENDER LENGTH (PIXELS)

FIGURE 2


MEAN MISSES
1.0
.5
0.0
MEAN CHAR/SEC
6.0
5.5
5.0
4.5
MEAN PIXELS/SEC
60
55
50
45
1
2
3
HORIZONTAL SPACING (PIXELS)

findings indicate that the descending component of a descender character in this character set should protrude below the line by at least two pixels.

Horizontal spacing between letters affected both measures of scanning rate. The rate in characters per second decreased significantly with each increase in spacing, while the rate in pixels per second increased significantly with each increase in spacing. Neither measure shows any indication of an approaching asymptote within the range of the independent variable employed. Obviously, the increase in rate of scanning with increasing character separation was not sufficient to keep the rate of character input at a constant value. These data by themselves would indicate that the minimum spacing is the most desirable since it would give the highest rate of information input. However, the analysis of miss frequency showed that a space of three pixels resulted in significantly fewer misses than the two smaller spacings, while the latter two did not differ. It appears, therefore, that a horizontal spacing of one or two pixels results in too high a rate of character input. The slower input rate at a spacing of three pixels is preferred because of the associated lower miss frequency. These data indicate that a space of three pixels should separate characters to maintain accurate letter identification.

The space between lines of letters did not significantly influence any of the dependent measures employed.

In summary, this experiment indicates that descender characters should extend at least two pixels below the line, that characters on a line should be separated by three pixels and that the space between lines does not influence letter recognition. These recommendations are different from those in the earlier paper, and indicate that descender length and letter spacing on a video display depend on the particular character set employed.

Reference

Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1962.

Placement of Accents on Characters

W.C. Treurniet & S. Latrémouille

Behavioural Research Group

Department of Communications

Placement of Accents on Characters

William C. Treurniet and Susane Latrémouille
Communications Canada

Either of two techniques can be used to draw accents on letters. These are the ENSEMBLE method and the COMPONENT method.

The ENSEMBLE Method: The accent and the letter are both described on a single character matrix and given a unique code. This method permits the letter to be compressed vertically in order to make room for the accent.

The COMPONENT Method: The accent and the letter are each described on separate character matrices. The accent is drawn over the letter by superimposing the accent matrix on the letter matrix.

The photographs of Figures 1 to 4 show how accented letters would appear using the ENSEMBLE method and three different applications of the COMPONENT method.

Samples of the ENSEMBLE Method:

Figure 1: The ensemble method is used to squeeze accents into the 5x7 character matrix. Both upper and lower case letters are reduced in height where possible to provide a space of one pixel between the accent and the letter. All accents are formed on the top two rows of the matrix.

Samples of the COMPONENT Method:

Figure 2: THe component method is used to place accents in the 5x7 character matrix. Accented letters are the same shape as those without accents. No accents are possible on upper case letters using this method. All accents are placed in the top two rows of the matrix.

Figure 3: The component method is used to place accents in the interline space which is three pixels wide. Accents are either two or three pixels high. The accented letters are the same size and shape as unaccented letters.

Figure 4: The component method is used to place accents in the interline space over upper case letters and extending into the top row of the character matrix over lower case letters. The accented letters are the same size and shape as unaccented letters. The method requires discrimination between upper and lower case letters so that an accent can be placed appropriately. Accents are either two or three pixels high.

Discussion:

Part (a) of each figure shows the most common accented letters in the French alphabet as they would appear using each method of drawing. Similarly, Parts (b) and (c) of each figure show the result of each method of drawing accents in the context of lower and upper case text, respectively. Figure 2(c) does not exist because the upper case letters for that drawing variation do not have accents.

Twenty francophone individuals were asked to rank the accented letters in Part (b) of each figure in order of preference (Appendix A). A Friedman analysis of variance on the ranks yielded a Chi-square of 37.8 which is highly significant ($p<.001$). This means that the pictures differed in terms of the ranks that they were given. Comparison of the ranks for each pair of pictures was performed using binomial tests. The number of times a picture was preferred over another picture was determined. Then, the probability that this frequency deviated from that expected by chance was calculated. Each of the six pairwise comparisons showed a significant difference at more than the ninety-five percent level of confidence.

The analysis shows that the techniques for drawing accents shown in Figures 1 to 4 were ranked in the following decreasing order of preference: Figure 4, Figure 3, Figure 1, and Figure 2. Further, no two methods can be considered equivalent in terms of preference.

The accented letters of Figures 2, 3 and 4 are designed so that they can be drawn using the component method. It should be noted, however, that these letters can also be created with the ensemble method. The designs of Figures 3 and 4 require only that the size of the character matrix be extended vertically. That is, the 5x7 character matrix must be enlarged to a 5x10 character matrix to include the interline space of three pixels.

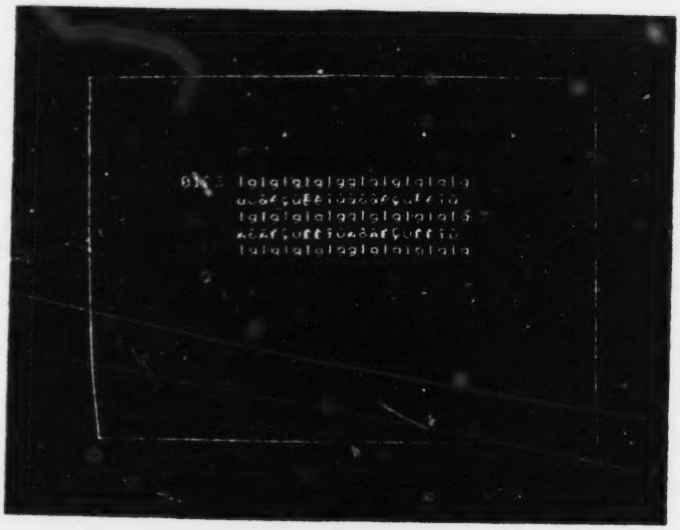
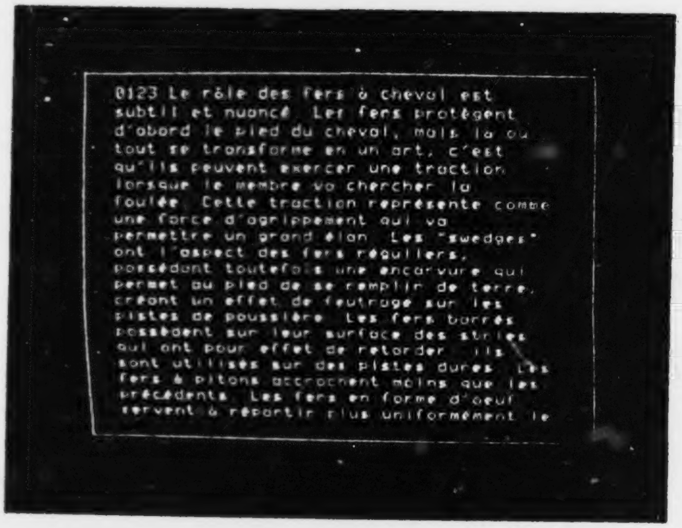
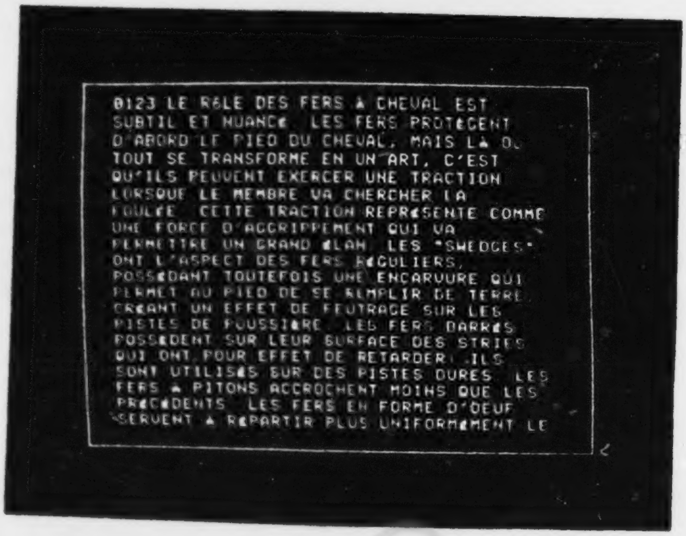


Figure 1(a)



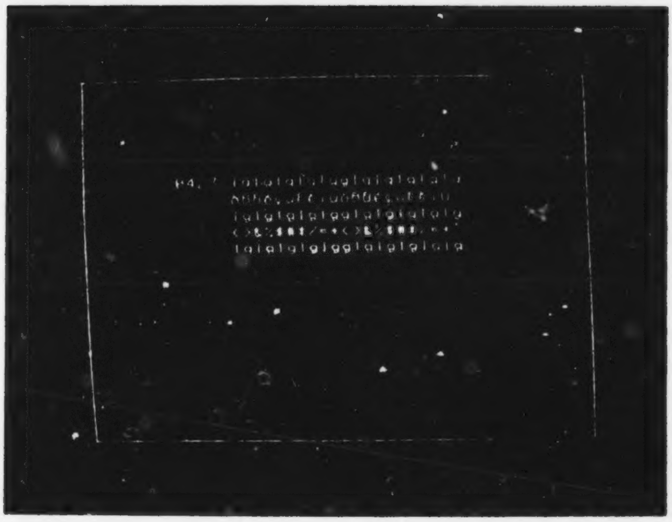
0123 Le rôle des fers à cheval est
subtil et nuancé. Les fers protègent
d'abord le pied du cheval, mais là ou
tout se transforme en un art, c'est
qu'ils peuvent exercer une traction
lorsque le membre va chercher la
foulée. Cette traction représente comme
une force d'agrippement qui va
permettre un grand élan. Les "swedges"
ont l'aspect des fers réguliers,
possédant toutefois une encarvure qui
permet au pied de se remplir de terre,
créant un effet de feutrage sur les
pistes de poussière. Les fers barrés
possèdent sur leur surface des stries
qui ont pour effet de retarder. Ils
sont utilisés sur des pistes dures. Les
fers à pitons accrochent moins que les
précédents. Les fers en forme d'oeuf
servent à répartir plus uniformément le

Figure 1 (b)



0123 LE RôLE DES FERS à CHEVAL EST
SUBTIL ET NUANCé. LES FERS PROTèGENT
D'ABORD LE PIED DU CHEVAL, MAIS Là OU
TOUT SE TRANSFORME EN UN ART, C'EST
QU'ILS PEUVENT EXERCER UNE TRACTION
LORSQUE LE MEMBRE VA CHERCHER LA
FOULéE. CETTE TRACTION REPRéSENTE COMME
UNE FORCE D'AGGRIPPEMENT QUI VA
PERMETTRE UN GRAND éLAN. LES "SWEDGES"
ONT L'ASPECT DES FERS RéGULIERS,
POSSéDANT TOUTEFOIS UNE ENCARVURE QUI
PERMET AU PIED DE SE REMPLIR DE TERRE,
CRéANT UN EFFET DE FEUTRAGE SUR LES
PISTES DE POUSSIèRE. LES FERS BARRéS
POSSèDENT SUR LEUR SURFACE DES STRIES
QUI ONT POUR EFFET DE RETARDER. ILS
SONT UTILISéS SUR DES PISTES DURES. LES
FERS à PITONS ACCROCHENT MOINS QUE LES
PRéCéDENTS. LES FERS EN FORME D'OEUF
SERVENT à RéPARTIR PLUS UNIFORMéMENT LE

Figure 1 (c)



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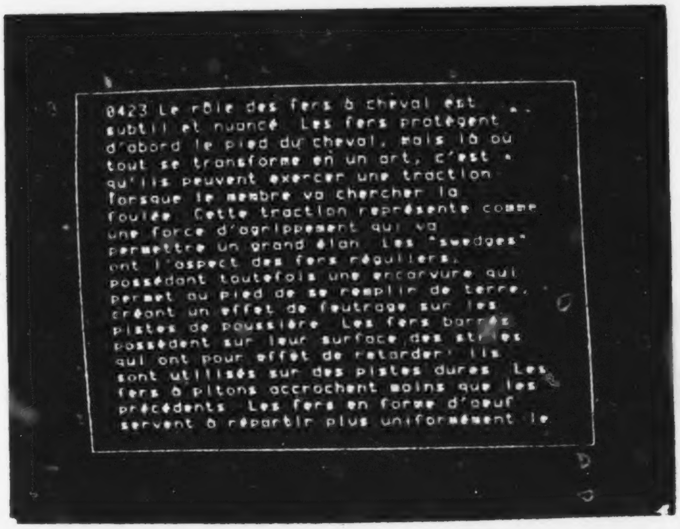

0423 Le rôle des fers à cheval est
subtil et nuancé. Les fers protègent
d'abord le pied du cheval, mais là où
tout se transforme en un art, c'est
qu'ils peuvent exercer une traction
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permettre un grand élan. Les "swedges"
ont l'aspect des fers réguliers,
possédant toutefois une encorvure qui
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pistes de poussière. Les fers barrés
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qui ont pour effet de retarder; ils
sont utilisés sur des pistes dures. Les
fers à pitons accrochent moins que les
précédents. Les fers en forme d'oeuf
servent à répartir plus uniformément le

Figure 2 (b)

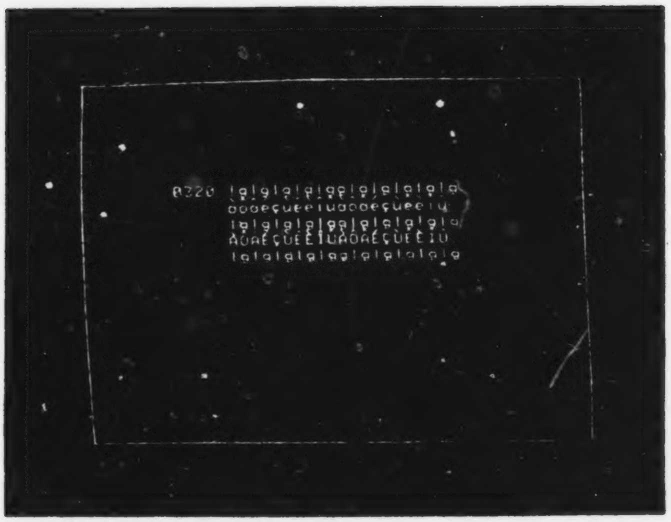

Figure 3 (a)

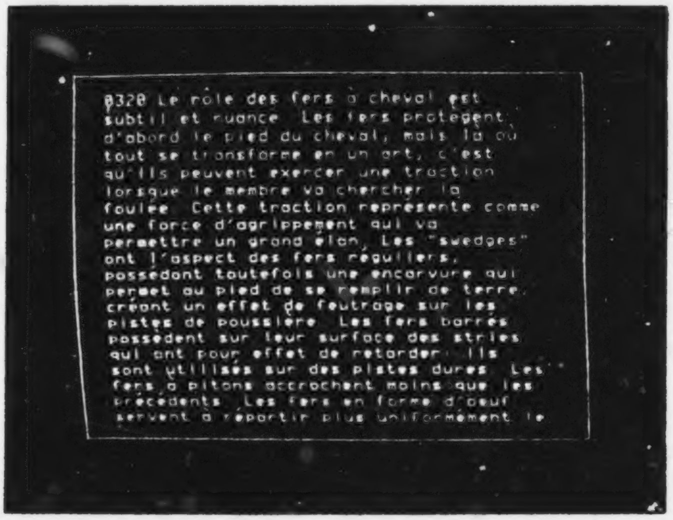

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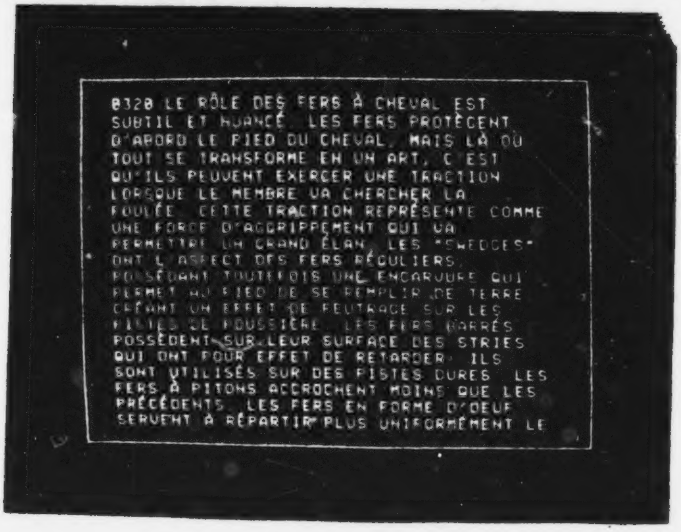
Figure 3 (b)



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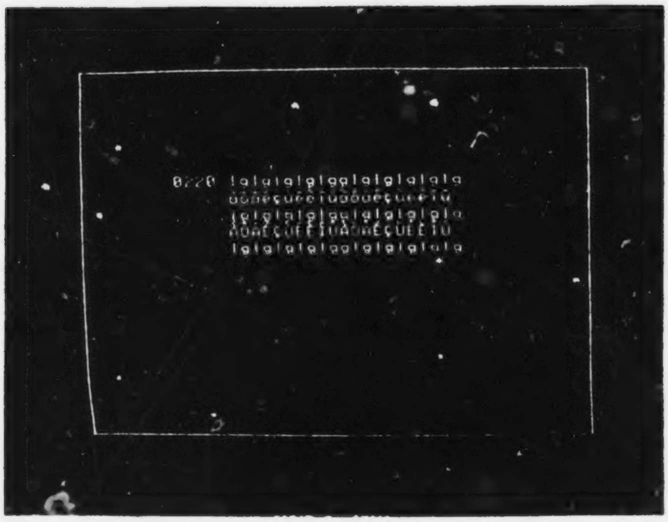
SERVENT À RÉPARTIR PLUS UNIFORMÉMENT LE

Figure 3 (c)



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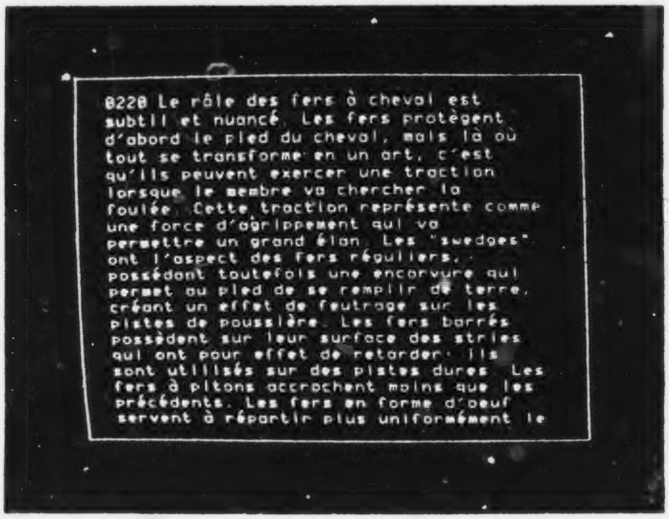

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Figure 4 (b)

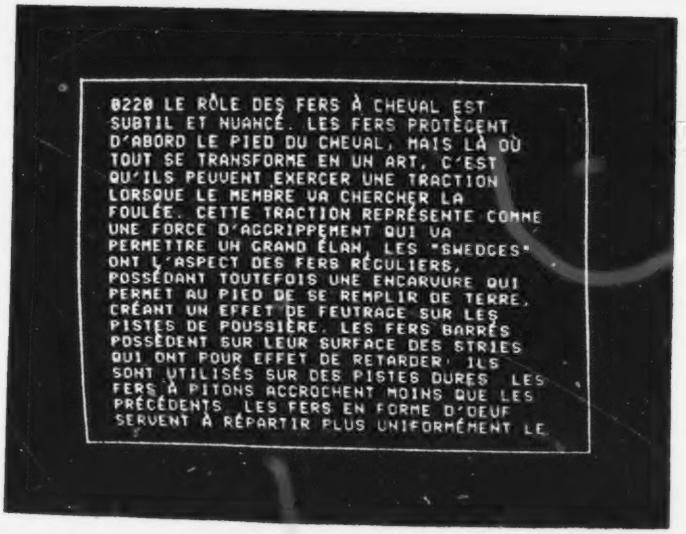

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Figure 4 (c)

Appendix A

A rank of "1" was assigned to the most preferred picture, and a rank of "4" was assigned to the least preferred picture. The number of times each picture received each of the four possible ranks is as follows:

Rank	Fig. 1	Fig. 2	Fig. 3	Fig. 4
1	1	1	1	17
2	4	0	13	3
3	10	6	4	0
4	5	13	2	0

CHAPTER III

HUMAN FACTORS RELATED TO INFORMATION BANKS

THE OPTIMUM NUMBER OF ALTERNATIVES TO DISPLAY ON AN INDEX PAGE IN AN INTERACTIVE TELIDON DATA BASE

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OTTAWA

SUMMARY

The answer to the question of the optimum number of alternatives that should be displayed on a Telidon index page has several practical ramifications. The purpose of this memo is:

a) To address this question from a behavioural perspective,

b) To develop a model for predicting the effects of varying the number of alternatives per index page, and

c) To describe the practical conclusions that can be drawn from this analysis.

For those readers uninterested in reading all the details of the analysis, a thumbnail sketch of the logic of this analysis plus the major conclusions derived from it are given in this brief summary. The detailed analysis with its discussion of assumptions and mathematical derivations is contained in the ANALYSIS section.

The version of Telidon currently being designed for pilot trails and initial commercial introduction provides a hierarchical tree-structure as the principal method to be employed by users for accessing target information. To locate a document in the data base using the tree, a user must choose among the alternatives displayed on each of a series of index pages. For a

fixed size of data base (that is, for a fixed number of documents in the data base), the number of index pages that must be accessed to locate target documents depends upon the number of alternatives displayed per index page and vice versa. Increasing the number of alternatives displayed on each index page decreases the number of index pages that must be accessed in tracing a target document.

Since fewer index pages must be accessed to locate any given document, there will also be a reduction in the total length of time spent by users in accessing index pages. At the same time, however, increasing the number of alternatives per page increases the number of alternatives that must be read per page, thereby increasing the time required by users to complete their search of each index page. The overall effect of the number of alternatives per page on the total length of time required by a user to find target information (i.e. documents) in the Telidon data base, hereafter called search time ST, will depend upon (a) the time it takes to read the alternatives on each index page (b) the time required to locate and press the appropriate keys on the keypad, and (c) the time it takes for the computer to respond to a request and display the next index page. The relative contribution of these three factors will determine whether the total search time is increased or decreased when the number of alternatives per page is increased.

The length of time required by a user to find information in the Telidon data base, i.e. search time, will probably be a fundamental determinant of system appeal and satisfaction for the user. It is reasonable to assume that people will refuse to use any retrieval system having excessively long STs. Thus, the shorter the average ST, the higher user acceptance and satisfaction with the system will be, and the more people will tend to utilize Telidon's services.

Total search times on this system will depend upon many factors such as number of documents in the data base, number of levels in the tree, number of choice alternatives offered on each index page, Telidon system response time, the rate at which people read, time to locate and press keys, and the search strategy employed by the individual user. On the basis of reasonable assumptions about both the rate at which people read and the strategies they employ in searching through the alternatives on an index page together with Bob Baser's projections for Telidon system response times (see attached memo), relatively accurate predictions of search times can be made. The analysis contained in the next section describes an appropriate behavioural model and illustrates its usefulness in answering the very practical question of what is the optimum number of alternatives to display on an index page. It should be noted that if the optimum exceeded 10, then this would be a strong argument in favour of using letters (permitting a maximum of 26) for labelling the alternatives. One implication of this alternative would be that a more expensive alphanumeric as opposed to a strictly numerical keyboard would have to be provided for each user.

The major conclusions to be drawn from this analysis (which is described in more detail in the next section) are:

1) The optimum number of alternatives per Telidon index page (in terms of minimizing the time users must spend searching through the tree) is less than 10 for a very wide range of possible conditions (see Tables 1 and 2).

2) Whenever possible, the number of alternatives on a page should be in the range of 4-8 which is optimal for most situations (see Tables 1 and 2).

3) Whenever possible information providers should avoid using only two alternatives per index page because search times for 2 alternatives per page are considerably longer than optimal (see Figures 1 and 2).

It is recommended that:

A NUMERICALLY-PAGED TREE INDEX WITH A MAXIMUM OF 10 ALTERNATIVES PER INDEX PAGE SHOULD BE USED ON TELIDON RATHER THAN AN ALPHABETICALLY-PAGED TREE WITH A MAXIMUM OF 26 ALTERNATIVES PER INDEX PAGE.

ANALYSIS

From preliminary observations of Telidon users, it is apparent that users can employ either of two distinct cognitive strategies in searching an index page for the correct alternative. A user can perform either an exhaustive search (ES) or a self-terminating search (TS). In an exhaustive search the user reads every alternative on an index page before making his/her selection which retrieves the next index page. In contrast, in a self-terminating search, the user reads alternatives only until encountering an alternative that meets his/her criterion of appropriateness, at which point the search is terminated and the next index page is retrieved. A decision is made to accept or reject each alternative as it is read. On the basis of my own casual observation of users, it appears that about three-quarters of these people have employed a self-terminating search strategy. (Of course, more systematic research would have to be conducted to establish the proportion of users employing each strategy.) However, I will show that the optimum is almost always less than 10 regardless of which strategy users adopt.

When searching an index page, all users seem to scan the alternatives on the page in sequence from top to bottom. A user who employs an exhaustive search strategy will always read all a alternatives on an index page. Therefore, the expected number of alternatives on a page that must be searched by such a user is simply $E(A) = a$. Initially at least, the alternatives on an index page will probably be arranged haphazardly. Therefore, assuming random sequencing of the a alternatives on a page, in the long run a user employing the self-terminating search strategy would have to read on the average one-half of the alternatives on each index page before encountering the target alternative, that is, $E(A) = a/2$.

Similarly, with alphabetical sequencing (and an approximately random selection of target alternative and approximately equal distribution of correct choices across alternatives), the $E(A) = a/2$ when a self-terminating search strategy is employed. (If the most frequently accessed alternatives happen to occur near the beginning of the sequence of index terms on a page, then $E(A) \rightarrow 1$. If, on the other hand, the most frequently accessed alternatives tend to occur near the end of the sequence, then $E(A) \rightarrow a$. However, over a large number of index pages it seems highly unlikely that the most frequently accessed index terms will all happen to begin with z or with a.)

Of course, after considerable experience, users might be able to recall the target index alternative and only have to scan rapidly the first letter of an alphabetized list of index alternatives to find its associated index number.

Scanning the first letter of the alternatives is certainly much faster than reading them. Thus, an experienced user might only have to read 2 or 3 alternatives on any given page before locating the target index alternative. In this case, the $E(A)$ would approach 1 and not $a/2$ for a self-terminating searches. However, the very size of proposed Telidon data bases will make it extremely difficult to recall all index terms because there will be so many to remember. Furthermore, a long series of psychological experiments (see any introductory psychology text) has amply demonstrated that our ability to recall words is greatly inferior to our ability to recognize words that we have seen before. And finally, the typical home user is just not likely to become a highly experienced Telidon user.

Although alphabetical sequencing has no effect on the expected number of alternatives that must be read on a page, sequencing by "frequency" could have a dramatic effect. The alternatives on an index page can be sequenced according to the relative frequency with which past users have accessed each alternative, placing the most frequently accessed alternative first on the page and the least frequently accessed alternative last. In the extreme case that one alternative on a page is almost always selected, then that alternative will be placed at the top of the list of alternatives and the $E(A) \rightarrow 1$ for the self-terminating search. At the other extreme, if all alternatives have been selected equally often, then the organization or sequencing of the alternatives will be essentially random and the $E(A) = a/2$ for the self-terminating search. In practice then, the facilitative effect of within-list organization by frequency in reducing total ST will be confined to those users employing a self-terminating strategy for searching index pages in which the alternatives have not been accessed equally often in the past.

The relationship between the number of documents in the data base (denoted d), the number of alternative index terms per level or page of the tree (denoted a), and the number of levels in the tree structure for the data base (denoted p, where p also represents the number of index pages that must be accessed by users to retrieve each document) is given by

$$(1) \quad d = a^p.$$

Given any 2 of the three variables (a, d, p), the third is fixed and can be computed by Equation 1 . For example, if there are 100,000 documents and 10 alternatives per level, then the number of levels is

$$(2) \quad p = \log d/\log a$$

$$= 5/1 = 5.$$

To locate a target document in the data base a total of p index pages (one page per level of this hierarchy) must be accessed. The time required to access each page and read the alternatives (recall that the average number of alternatives read per page, E(A), varies with the search strategy employed by the user) is

$$(3) \quad T = E(A) \cdot t_a + t_{kp} + t_{rt}$$

where E(A) = expected number of alternatives on a page that must be searched before the target index term is found;

t_a = time required to read and process one alternative (i.e. reading rate for users);

t_{kp} = time interval between the completion of reading the alternatives on an index page and the actual pressing of the keys;

t_{rt} = response time of the computer, i.e., the time between the last key press and the onset of the next index page.

Thus, the total search time is just p times Equation 3 or

$$\text{(4)} \quad ST = p(E(A) \cdot t_a + t_{kp} + t_{rt})$$

where ST = total search time;

p = number of levels in the tree.

By substitution of $d = a^p$

$$\text{(5)} \quad ST = \frac{E(A) \cdot t_a + t_{kp} + t_{rt}}{\log a} \log d$$

where d = number of documents in data base, and

a = number of alternatives per index page.

From Equation 5, it can be seen that the number of documents in the data base (represented by log d) does not affect the optimum number of alternatives. That this is true can be seen by considering Figure 1 which is a plot of the relationship between the number of alternatives per page, a, and ST. In Figure 1, the STs plotted are for a data base with 10 documents (therefore, log d = 1).

To obtain the STs for a data base with 100 documents ($\log d = 2$), the STs in Figure 1 must all be multiplied by the constant $\log d = 2$. In plotting the relationship between ST and a for a data base of size $d = 100$, one simply has to double all values on the ordinate (i.e. double the ST values). Note that the resultant plot would be identical to Figure 1 except that the ordinate values are doubled. The optimum number of alternatives per page does not change with changes in d, that is, the lowest point on each curve in Figure 1 remains the lowest when d is changed. Therefore, in all further calculations the size of the data base is arbitrarily set at 10 and, thus $\log_{10} d = 1$. The term $\log d$ then drops out of Equation 5 . (The size of the data base, however, does affect ST. The ST for a given size of data base can be easily determined by multiplying the reported STs by $\log d$. For example, the ST for a document in a data base containing just 10 documents is given directly by Figure 1. The ST for a document in a data base containing 100,000 documents can be obtained by multiplying the appropriate value of ST in Figure 1 by $\log 100{,}000 = 5$).

RESULTS

For any given combination of number of users, search strategy, and reading rate, there is an optimum number of alternatives that should be displayed per index page to minimize total ST (see Figures 1 and 2). Tables 1 and 2 present the optimum number of alternatives for a wide range of possible situations.

For example, empirical observations suggest that most people require 1/2 to 1 second to locate and press the appropriate keys on the keypad. Figure 1 and Table 1 present predicted search times and predicted optimum numbers of alternatives, respectively, based on the assumption that people take 1/2 second on the average to locate and press the keys. The predictions depicted in Figure 2 and Table 2 are based on the assumption that the average key press time is 1 second.

The number of users on Telidon simultaneously is varied systematically from 1 to 120. The corresponding Telidon response times, which depend upon the number of users, range from the optimum predicted by Bob Baser to a very slow response time. The reading times per alternative in Tables 1 and 2 range from a theoretical minimum of 1/4 sec per alternative (that is, a saccadic eye movement, with an average duration of 200-250 msec, is required to move the eye from one alternative to the next) to an extremely slow 2 sec per alternative (which is roughly equivalent to an extremely slow reading speed of 30-60 words per minute). Bill Treurniet estimates that average reading speed is approximately 240 words per minute which is roughly equivalent to .5 seconds per alternative. Finally, both search strategies -- exhaustive and self-terminating -- are represented in the table.

Inspection of Tables 1 and 2 reveal that the optimum number of alternatives for an extremely wide range of possible conditions is less than 10. Only when extremely fast readers are using a highly overloaded system (i.e. over 100 users simultaneously retrieving information which slows computer response time down quite a bit) does the optimum ever exceed 10 alternatives/page.

Even then, search times under such conditions are relatively close to being optimal if 10 alternatives are displayed on each page. The practical implication is that a *numerically paged tree structure with a maximum of* 10 alternatives per index page should be used for Telidon data bases rather than an alphabetically paged tree with a maximum of 26 alternatives per index page. If possible, the number of alternatives on a page should be in the range of 48 which is optimal for most situations (see Tables 1 and 2 and Figures 1 and 2).

Although STs for 10 or fewer alternatives per page are faster (under most conditions), than for 26 alternatives per page, the reverse can be true under special conditions. When the alternatives are arranged sequentially on an index page by the frequency with which the alternatives are chosen and the probability or relative frequency of choosing one of the alternatives approaches 1, ST should actually be faster with 26 instead of 10 alternatives per page. The relationship is given as follows:

$$(6)\quad ST_{a=2} = \left(\frac{\log 10}{\log 26}\right) ST_{a=10}$$

$$= .7067\ ST_{a=10}$$

Under these conditions, a 30% savings in total search time can be made by using 26 alternatives per page rather than 10 alternatives. In fact, under these conditions the more alternatives there are per index page the faster the searches can be made. The practical limit appears to be 40 alternatives per page (2 rows of 20 alternatives each). Thus the greatest savings in total search time that could be made would be:

$$(7)\quad ST_{a=40} = \left(\frac{\log 10}{\log 40}\right) ST_{a=10}$$

$$= .6242\ ST_{a=10}$$

It is important to remember, however, that these conditions are very unlikely to be met in practice. Up to this point in the analysis it has been implicitly assumed that all textual information on a page is displayed simultaneously. There are actually three variations in the rate of display for Telidon systems: (a) each page is displayed instantaneously, (b) text is displayed line by line but at a rate faster than users can read the already displayed alternatives, and (c) text is displayed line by line and at a rate slower than users can read the displayed alternatives. The analysis developed up to this point in this memo applies to both situations (a) and (b).

When text is displayed line by line more rapidly than it can be read, the text can be considered to be displayed simultaneously because it does not reduce the reading rate (which is a parameter in the analysis presented thus far). When text is displayed line by line at a slower rate than users can read, however, reading rate must slow down. In this case, the rate of reading alternatives t_a must now equal the rate of display t_d, that is, the maximum rate of reading can be no higher than the limit set by the rate of display t_d. Situation (c), then, can also be studied using the present analysis by setting user reading rate t_a equal to the rate of display t_d.

The present Telidon rate of display is 1200 band or 120 char/sec (see attached memo by Bob Baser). The estimated number of characters/index alternative in the present data base, based on a sample of 25 alternatives, is.13.66 char/index alternative (or approximately equal to 2 words/alternative). This estimate includes 2 characters for the index number associated with each alternative and 1 character for the PDI instruction at the end of the alternative. Thus, the display rate t_d equals (120/13.66 = 8.78 alternatives per second or) 1/10 sec/alternative which exceeds the theoretical maximum rate of reading of 1/4 sec/alternative. Therefore, the system can be treated as if each page was displayed instantaneously, and the present analysis applies to the Telidon system currently being developed.

The present analysis is based on the assumption that computer response times will not vary significantly as the size of the data base increases. This assumption will be approximately true if disks for storing the information are almost completely filled. Computer search times are relatively constant across different sizes of disks. Thus, even though five times the amount of information must be searched on a 180-megabyte disk compared with a 30-megabyte disk, the average computer response times are about the same. If, however, a very large disk is used to store a small amount of information (eg. 30-megabytes of information on a 180 megabyte disk), then computer response times will be somewhat faster than that predicted by Bob Baser in his graph. When data base size is much smaller than disk storage size, the results and conclusions presented in this memo do not apply. Nevertheless, Equation 5 of the present memo can be used to generate predictions for such situations by substituting in the appropriate values for computer response times.

As in any physics or economics model, predictions are only as good as the model assumptions. Empirical research can, and should, be conducted to substantiate the assumptions made in the present model.

TABLE 1

OPTIMUM NUMBER OF ALTERNATIVES ON A TELIDON INDEX PAGE ASSUMING ONE-HALF SEC REQUIRED TO PRESS KEYS (i.e. $t_{kp}=1/2$)[a]

USER SEARCH STRATEGY	READING TIME PER ALTERNATIVE	NO. OF USERS (TELIDON RESPONSE TIME[b])			
		1-60(.55)	80(.60)	100(.90)	120(1.35)
EXHAUSTIVE	.25 sec	6	6	6/7[c]	7
	.50	4	4	5	5/6
	1.00	4	4	4	4
	2.00	3	3	3	4
SELF-TERMINATING	.25 sec	8	8	9	11
	.50	6	6	6/7	7
	1.00	4	4	5	5/6
	2.00	4	4	4	4

[a] The optimum does not vary with changes in the size of the data base (i.e. the total number of documents). In other words, the optimum values reported in this table hold for any number of documents.

[b] Measured in seconds. These Telidon response times, t_{rt}, are based on Bob Baser's (July, 1979) predictions for the yet-to-be developed Telidon system.

[c] Both 6 and 7 are optimum.

TABLE 2

OPTIMUM NUMBER OF ALTERNATIVES ON A TELIDON INDEX PAGE

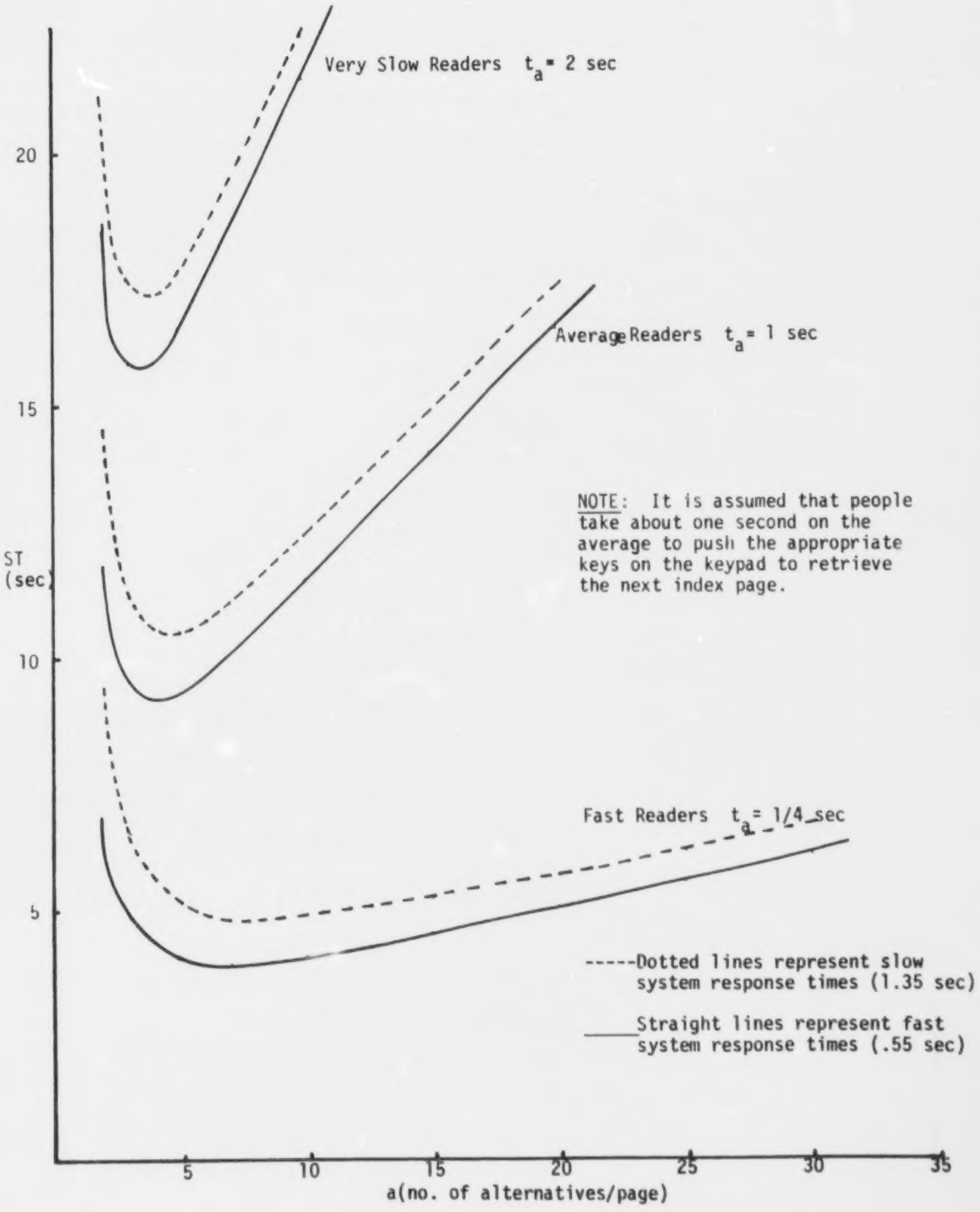
ASSUMING ONE SEC REQUIRED TO PRESS KEYS (i.e. $t_{kp}=1$)[a]

USER SEARCH STRATEGY	READING TIME PER ALTERNATIVE	NO. OF USERS (TELIDON RESPONSE TIME[b])			
		1-60(.55)	80(.60)	100(.90)	120(1.35)
EXHAUSTIVE	.25 sec	7	7	7/8	8
	.50	5	5	5	6
	1.00	4	4	4	5
	2.00	3	3	4	4
SELF-TERMINATING	.25 sec	10	10	11	12/13
	.50	7	7	7/8	8
	1.00	5	5	5	6
	2.00	4	4	4	5

[a] The optimum does not vary with changes in the size of the data base (i.e. the total number of documents). In other words, the optimum values reported in this table hold for any number of documents.

[b] Measured in seconds. These Telidon response times, t_{rt}, are based on Bob Baser's (July, 1979) predictions for the yet-to-be developed Telidon system.

Figure 1. Search Time as a Function of the Number of Alternatives per Index Page When People Use An Exhaustive Search Strategy

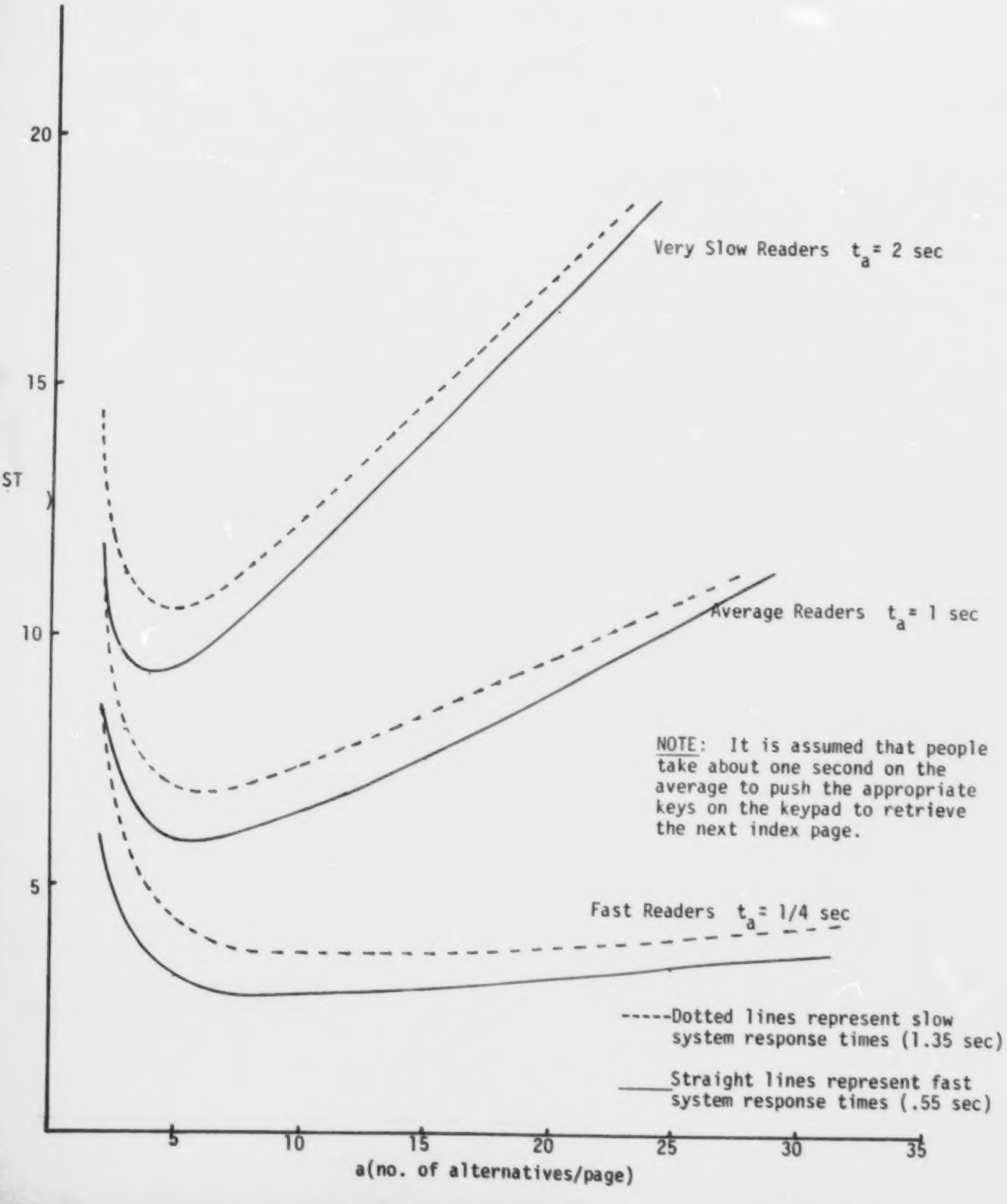


NOTE: It is assumed that people take about one second on the average to push the appropriate keys on the keypad to retrieve the next index page.

-----Dotted lines represent slow system response times (1.35 sec)

____Straight lines represent fast system response times (.55 sec)

Figure 2. Search Time as a Function of the Number of Alternatives per Index Page When People Use A Self-terminating Search Strategy



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____Straight lines represent fast system response times (.55 sec)

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MEMORANDUM **NOTE DE SERVICE**

TO / À	Eric Lee
FROM / DE	Robert Baser
SECURITY-CLASSIFICATION-DE SÉCURITÉ	
OUR FILE — N/RÉFÉRENCE	
YOUR FILE — V/RÉFÉRENCE	
DATE	5 June 1979

SUBJECT / OBJET Response time of the Telidon Data Base

I am including for your use a graph of the response times of our present data base as predicted from theoretical calculations.

The response time for this system has been defined to be the time delay between the pressing of the ● button at the user terminal and the reception of the first character of a page at the terminal. No account has been taken of the display time. The display time may, however, be estimated as follows:

256 characters

|_(2.13 sec.)_| .25 sec |________| ....

Blocks of 256 characters are transmitted in a period of 2.13 seconds with a 0.25 second delay between blocks.

Initial analysis shows that the delays can be allocated as follows:

- line turnaround (.25 sec on transmission and .25 sec on reception of the first character)
- front-end CPU usage (18-50 msec)
- host CPU range (.5-1 msec)
- disk access (0.016-2,400 msec)

The first three delays tend to be constant independent of the number of users attached to the system and have been assumed to be 500 msec for line turnaround and conservatively 50 msec for CPU usage in the system.

The disk usage presents a major bottleneck to the system and its response is highly dependent on the number of users attempting to access the system. The disk can be considered to be a single server queue with a constant service time of 80 msec. Hence queuing theory can be used to

......2

calculate the mean wait time for service and the variation about the mean. The attached graph is the result of these calculations assuming page request are uniformly distributed.

In actual fact, the amount of requests may not be uniformly distributed since flipping through index pages on the tree may proceed very rapidly whereas document pages may be read very slowly. In addition, the disk service time is not constant but depends on a number of factors, including the key sequence entered and the position of the page on the disk. However, only a complex simulation model or actual measurements on the system will determine the actual response times.

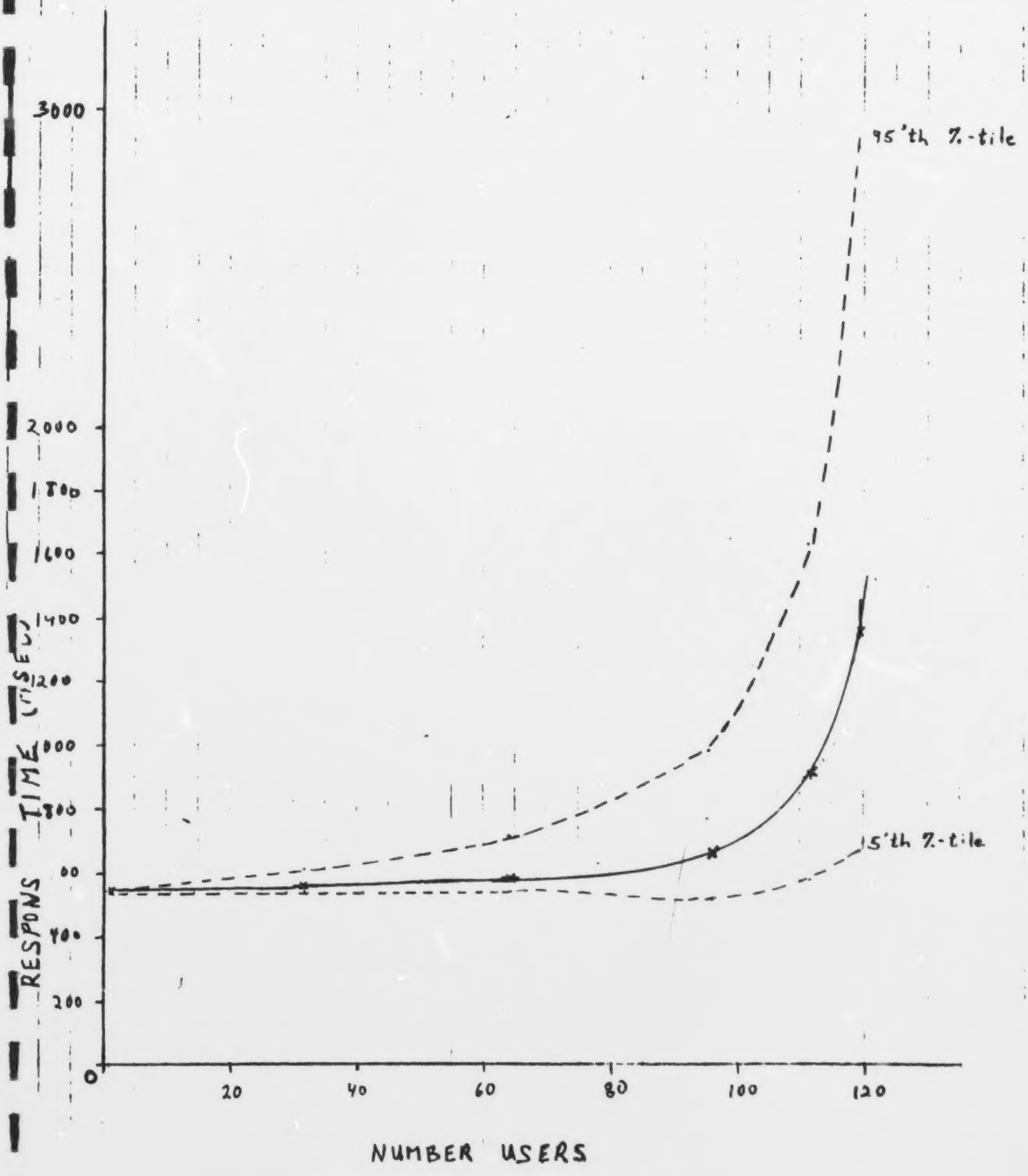
I hope this meets your needs for the present. I will be writing a more detailed report on response times in the near future and will send you a copy as soon as it is completed.

Robert Baser
Image Communications

RB:pt

Encl.

TELIDON DATA BASE



BROADCAST TELIDON:
THE OPTIMUM NUMBER OF ALTERNATIVES PER INDEX PAGE

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December 1979

BROADCAST TELIDON: THE OPTIMUM NUMBER OF ALTERNATIVES PER INDEX PAGE

SUMMARY

The conclusions of this study are as follows:

A. BROADCAST TELIDON WITH VBI TRANSMISSION

(1) FOR SMALL DATA BASES WITH APPROXIMATELY 100 DOCUMENT PAGES, INFORMATION PROVIDERS SHOULD DISPLAY BETWEEN 7 AND 13 ALTERNATIVES/PAGE. FOR LARGER DATA BASES WITH APPROXIMATELY 300 DOCUMENT PAGES, 15-20 ALTERNATIVES SHOULD BE DISPLAYED ON EACH INDEX PAGE.

(2) THE USE OF VERY FEW ALTERNATIVES/PAGE (E.G. 2 OR 3) SHOULD DEFINITELY BE DISCOURAGED.

(3) IF THE NUMBER OF ALTERNATIVES/PAGE IS LIMITED TO A MAXIMUM OF 10, THEN (A) AS MANY ALTERNATIVES AS POSSIBLE SHOULD BE DISPLAYED ON EACH PAGE AND (B) AT LEAST 6 ALTERNATIVES SHOULD BE DISPLAYED ON EACH PAGE TO MINIMIZE SEARCH TIME.

(4) DATA BASES SHOULD PROBABLY BE RESTRICTED TO A MAXIMUM OF 300 PAGES.

B. BROADCAST TELIDON WITH FULL-CHANNEL TRANSMISSION

(5) THE NUMBER OF ALTERNATIVES/PAGE CAN BE LIMITED TO A MAXIMUM OF 10 WITHOUT SIGNIFICANTLY INCREASING SEARCH TIMES.

(6) AS MANY ALTERNATIVES AS POSSIBLE SHOULD BE DISPLAYED ON EACH PAGE. AT LEAST 6 ALTERNATIVES/PAGE SHOULD BE DISPLAYED.

(7) EVEN FOR A DATA BASE AS LARGE AS 15,000 PAGES, LESS THAN TWO MINUTES ON THE AVERAGE SHOULD BE REQUIRED FOR A USER TO SEARCH THROUGH THE DATA BASE INDEX AND LOCATE THE INFORMATION WANTED.

This memo addresses the problem of how many alternatives should be displayed on each index page in order to minimize the time required to find information (i.e., search time) by broadcast Telidon users. Two methods of broadcasting will be considered: (a) vertical-blanking-interval (VBI) transmission in which information is broadcast over the hidden TV lines of each TV frame (i.e., only part of a TV channel) and (b) full-channel transmission. Three analyses will be presented:

(A) the optimum for VBI transmission when the number of documents in the data base is fixed and known,

(B) the optimum number of alternatives/page for VBI transmission when the size of the data base (document pages plus index pages) is fixed and known, and

(C) the optimum for full-channel transmission when the size of the data base is fixed and known.

The length of time required by a user to find information in the data base, i.e. search time, will probably be a fundamental determinant of system appeal and satisfaction for the user. It is reasonable to assume that people will refuse to use any retrieval system having excessively long search times (STs). Thus, the shorter the average ST, the higher user acceptance and satisfaction with the system should be, and the more people should tend to utilize Telidon's services.

Search time varies as a function of six different factors: (a) the time it takes to read the alternatives on each index page, (b) the time required to select and press the appropriate keys on the keypad, (c) the average waiting time until the correct page is grabbed by the terminal from the continuous stream of database pages being broadcast sequentially over the TV channel, (d) the average number of pages in each document, (e) the strategy employed by users in their search for information, and (f) the number of alternatives displayed on each index page.

Formulae were derived giving the relationship between ST and those 6 factors. Then, these equations were used to generate predicted STs by substituting in estimated reading rates, computer response times, data base sizes, average sizes of documents, no. of alternatives/page, etc.

The major results of these three analyses are as follows:

A. Broadcast Telidon with VBI Transmission:

(1) Too few or too many alternatives/page produces excessively long search times. The shortest search times occur for an intermediate number of alternatives/page; see Figures 2 and 3.

(2) The time required to find information in the data base when only 2 alternatives are displayed on each index page could require anywhere from 2 1/2 to 6 1/2 times as long as the optimum ! (Analysis A)

(3) The optimum number of alternatives per index page is always 10 or greater for data bases containing 100 or more document pages; see Table 1. (That is, information can be found most quickly when there are more than 10 alternatives per page.)

(4) Limiting the number of alternatives per page to a maximum of 10 will increase the time required to find information in the data base over the optimum search time. However, for a maximum of 10 alternatives/page, search times can be kept with 41% of the optimum provided that the "local" optimum number of alternatives/page (i.e., the number of alternatives/page between 2 and 10 that minimizes search time) is employed.

(5) If the number of alternatives per page is limited to a maximum of 10, then as many alternatives as possible should be displayed on each page. Fewer than 6 alternatives/page should definitely

be avoided because the search times become seriously inflated. When limited to displaying a maximum of 10 alternatives/page, search time is minimized under almost all conditions by displaying the maximum of 10 alternatives on each index page.

(6) The optimum number of alternatives per page depends critically on the size of the data base; see Tables 1 and 2. The optimum increases as the number of document pages (or the total number of data-base pages) increases; see Figure 1.

(7) Data bases containing more than 300 document pages will probably require more time to search and retrieve target information than most people would be willing to spend. Search times would probably average anywhere from 3 to 7 minutes! (See Figures 2 and 3.)

B. Broadcast Telidon With Full-Channel Transmission

(8) The optimum number of alternatives per index page is less than 10 for some conditions and greater than 10 for other conditions (see Tables 3 and 4).

(9) Limiting the number of alternatives displayed per page to a maximum of 10 can increase search time up to 21% above the optimal. Under most of the conditions considered, however, search times for a maximum of 10 alternatives/page are within 10% of the optimal.

(10) Search times are exceedingly long when compared with the optimum for fewer than 6 alternatives/page. For example, search times with 2 alternatives/page range anywhere from 30 to 300% longer than the optimum. Increasing the number of alternatives/

page can reduce search times significantly, although even as many as 5 alternatives/page can lengthen search time by 56% over the optimum.

(11)

DATA BASE SIZE	PREDICTED SEARCH TIMES*
5,000 pages	23- 79 sec
10,000 pages	41-113 sec
15,000 pages	59-140 sec

* Assumes effective data rate equal to 362,880 bytes/second.

DEFINITIONS

waiting time (t_{rt}) - the time that a user must wait after making a page request until the page begins to be displayed. Waiting time is equivalent to computer response time for interactive Telidon and to the broadcast response time for broadcast Telidon.

search time (ST) - the time required by a user to complete a search through the data base tree index and find the document wanted; it is the time from when the user begins his search on Telidon until the document is retrieved, and it includes the time required to retrieve each of the index pages in the sequence leading to the document. NOTE - that search time and waiting time are not the same thing at all. Waiting time is the time that a user spends waiting for a single page to be retrieved whereas search time is the time that a user spends retrieving many index pages until the target document is retrieved.

data base - consists of all the pages of information that can be retrieved by a user and displayed on a Telidon terminal (or modified TV). It consists of both document pages and index pages.

document - is a collection or set of pages (called document pages) containing the information of interest to users. A document page is a content page. A data base can contain many documents, each document consisting of many document pages.

index - is the set of pages (called index pages) which the user can use to locate target documents. Each index page consists of a number of alternatives. An index page is also called a menu page.

P = the total number of pages in the data base, including both index and document pages;

d = the number of documents in the data base;

i = the number of index pages in the data base;

a = the number of alternative choices offered on each index (i.e., menu) page.

INTRODUCTION

The present analyses are based on a similar analysis for interactive Telidon (see Tech. Memo BRG 79-4). The reader is directed to that memo for a more detailed discussion of the assumptions and conditions underlying this type of analysis.

To assist users in their search for information in a data base, a tree index can be provided. To locate a document in the data base using the tree, a user must choose among the alternatives displayed on each of a series of index pages. For a given data base the number of index pages that must be accessed to locate the target document depends upon the number of alternatives displayed per index page and vice versa. Increasing the number of alternatives displayed on each page decreases the number of index pages that must be accessed in retrieving a target document.

Since fewer index pages must be accessed to locate any given document, there will also be a reduction in the total length of time spent by users in accessing index pages. At the same time, however, increasing the number of alternatives per page increases the number of alternatives that must be read per page, thereby increasing the time required by users to complete their search of each index page. The overall effect of the number of alternatives per page on search time (the total length of time required by a user to find target information in the teletext data base), will depend upon (a) the time it takes to read the alternatives on each index page, (b) the time required to select and press the appropriate keys on the keypad, (c) the average waiting time until the correct page is grabbed by the terminal from the continuous stream of database pages being broadcast sequentially over the TV channel, (d) the average number of pages in each document and (e) the strategy employed by users in their search for information. The relative contribution of these five factors will determine whether the total search time is increased or decreased when the number of alternatives per page is increased.

The length of time required by a user to find information in the data base, i.e. search time, will probably be a fundamental determinant of system appeal and satisfaction for the user. It is reasonable to assume that people will refuse to use any retrieval system having excessively long search times (STs). Thus, the shorter the average ST, the higher user acceptance and satisfaction with the system should be, and the more people should tend to utilize Telidon's services.

ANALYSIS A

BROADCAST TELIDON WITH VBI TRANSMISSION (OPTIMUM AS A FUNCTION OF NUMBER OF DOCUMENTS)

In the analysis of interactive Telidon (TECH MEMO BRG 79-4), the relationship among the number of documents in the data base (denoted d), the number of alternatives per index page (a), and the number of index pages that must be accessed to locate target information (p) was given by:

$$(1) \qquad d = a^p$$

or equivalently by:

$$(2) \qquad p = \log d/\log a$$

When p, a, and d are all integers, Equation 2 gives the exact number of index levels that must be accessed to retrieve any document. In such cases, any document requires exactly p index pages to retrieve. However, when some documents in the data base require more index pages to retrieve than others, the average number of index pages required to retrieve a randomly selected document could be anywhere from the minimum to the maximum number of index pages required to access a document in the data base. That is,

$$p_n \leq \bar{p} \leq p_m$$

where $\bar{p}$ = the average length of path through the tree (that is, the average number of index pages that must be accessed to retrieve a target document);

p_m = the maximum number of index pages required to retrieve a document in a given data base;

p_n = the minimum number of index pages required to retrieve a document in a given data base.

In this case, Equation 2 only provides an approximation of the average number of index pages.

For large data bases and relatively rapid computer response times (as considered for Telidon in TECH MEMO BRG 79-4), Equation 2 provides a more than adequate approximation of this average for use in computing search times. For the small data bases and relatively long waiting times that will be characteristic of broadcast Telidon, however, the use of Equation 2 can lead to serious errors. The following analysis will be used to compute accurate search times based on a more precise estimate of the number of index pages that must be accessed to retrieve target documents.

Let p_m represent the maximum number of index pages that must be accessed to retrieve a document in a given data base. Then the maximum number of index pages at level p_m of the data base is $a^{p_m - 1}$. If each of those index pages accessed a documents, then the maximum number of documents that could be accessed at the highest index level p_m is a^{p_m}. However, if the actual number of documents in the data base is less than the maximum number possible (that is, if $d < a^{p_m}$), then $a^{p_m} - d$ of the possible document positions at the bottom level of the tree will not be filled by documents and can therefore be dropped from the tree. Furthermore, some of the index pages at level p_m will not be needed (for index pages are not needed to access documents that do not exist). Each of these unnecessary index pages at level $\underline{p}_m$ can be replaced by one of the $\underline{d}$ document pages from level $\underline{p}_m+1$ of the tree with a consequent reduction of $\underline{a}$ in the number of documents that can be accessed at level $\underline{p}_m+1$ of the tree. However, since a document from the bottom level ($\underline{p}_m+1$) of the tree has been moved up one level in the tree, there is an actual reduction of only $\underline{a} - 1$ in the number of document positions that do not need to be accessed (because these documents do not exist). In other words, the index pages not needed at level $\underline{p}_m$ of the tree can be considered to have accessed one actual and a - 1 non-existent documents. The non-existent documents are dropped and since there is only a single actual document remaining, it can replace the unnecessary index page at level $\underline{p}_m$. Thus, for every $\underline{a} - 1$ documents dropped from level $\underline{p}_m+1$ of the tree, there will be one actual document placed at level $\underline{p}_m$ of the tree. The number of documents accessible from the second last (i.e. $\underline{p}_m - 1$) and the last (i.e. $\underline{p}_m$) index levels of the tree are, respectively:

$$(3) \quad n = \left\lfloor \frac{a^{p_m} - d}{a - 1} \right\rfloor$$

$$(4) \quad m = d - n$$

where n = the number of document requiring $\underline{p}_m - 1$ index pages to retrieve each (that is, the number of documents at level $\underline{p}_m$ of the tree);

m = the number of documents requiring p_m index pages to retrieve each (that is, the number of documents at level $p_m - 1$ of the tree);

p_m = the maximum number of index pages that must be accessed in retrieving a document;

$\lfloor\ \rfloor$ = denotes that the value of the term within the semi-brackets should be truncated, that is, the fraction should be dropped to leave an integer number. (For example, if a = 3, d = 12, $p_m = 3$, then $n = \lfloor 7.5 \rfloor = 7$.)

Note that all $\underline{d}$ documents in the data base are accessible from the last two levels of the tree.

The term within the semi-brackets in Equation 3 can take on fractional values. However, since the number of documents at level p_m of the tree must be an integer value, the semi-brackets are required to integerize the term. Fractions of documents cannot occur in this system. The term on the right hand side is truncated rather than rounded up to the next whole integer because, when a-1 does not divide evenly into $a^{p_m} - d$, it implies that there is a remainder of less than a-1 unnecessary documents at the base of the tree. Since the potential for displaying an entire set of a-1 documents is lost whenever an actual document is substituted for an index page at level p_m of the tree, the ability to display some actual documents would be lost because only a-1 unnecessary document positions remain. The extra actual documents, therefore, must be displayed at the base of the tree (i.e. at level $p_m + 1$).

It should be noted that the value of p_m to be used in Equation 3 is given by

$$(5)\quad p_m = \lceil \log d/\log a \rceil$$

where the semi-brackets indicate the value of the term within the brackets should be rounded up to the next higher integer. (For example, if $d = 12$, $a = 3$, then $p_m = \lceil 2.26 \rceil = 3$.)

The term on the right hand side of Equation 5 is rounded up to the next whole integer because any fraction (no matter how small) necessarily implies that an extra level must be added somewhere to the tree in order to accomodate the extra documents. Consider, for example, a data base containing 100 documents with 10 alternatives per index page ($d = 100$; $a = 10$). Only 2 index levels are required to access any of the 100 documents. But adding just one more document to the data base requires adding a third level to the index pages to access the extra document.

Recall that every document is accessible on either the last or second last level of the tree.

Assuming that every document is accessed equally often, the probability that the document being sought will require $\underline{p}_m$ index levels is m/d because $\underline{m}$ of the $\underline{d}$ documents are at level $\underline{p}_m$. Similarly, the probability that it will require $\underline{p}_m - 1$ index levels is n/d:

(6) $P(I = p_m) = m/d$

(7) $P(I = p_m - 1) = n/d$

where I = the number of index levels that must be accessed;
$P(I = p_m)$ = the probability that $\underline{p}_m$ index levels will be required to retrieve a document.

Therefore, the average length of path through the tree (i.e. the average number of index pages that must be accessed to find target information) is given by:

(8) $$\overline{p} = (n/d)(p_m - 1) + (m/d)(p_m)$$

$$= p_m - n/d$$

John Storey estimates that 100 data-base pages can be wrapped around (cycled) in 20 seconds using the hidden TV lines on a given TV channel. That is, each page of broadcast Telidon information requires 1/5 second to transmit. However, assuming random entry of request in cycle, the expected number of pages (index and documents) that must be cycled past the frame grabber before reaching the target page is given by: 1/2 P. Then

(9) $$t_{rt} = t_b \cdot 1/2\ P$$

$$= 1/5 \cdot 1/2\ P$$

$$= 1/10\ P$$

where t_{rt} = expected response time until target page is displayed in broadcast mode (i.e. waiting time);

t_b = average time required to broadcast a single page of information;

P = the total number of pages in the data base (including documents and index pages).

$$(10)\quad t_c = t_b \, . \, P$$

$$= 1/5 \, P$$

where t_c = maximum waiting time until target page is displayed in the broadcast mode, also called cycle time.

The total number of pages in the data base, P, including both index and document pages, is given by:

$$(11)\quad P = d + i$$

where i = the number of index pages. The $\underline{k}^{th}$ level of the index consists of $\underline{a}^{k-1}$ pages. The total number of index pages is the sum of the number of index pages at each level of the tree.

$$(12)\quad i = a^0 + a^1 + \ldots + a^{p_m - 2} + (a^{p_m - 1} - n)$$

The last term in Equation 12 is the number of index pages at the last index level (i.e. $\underline{p_m}$). Recall that $\underline{n}$ of the maximum number of index pages possible at this level have been replaced by document pages. By summing over all preceeding terms, we have:

$$(13)\quad i = \sum_{k=0}^{p_m - 1} a^k + (a^{p_m - 1} - n)$$

By substitution, Equation 11 is equivalent to:

$$(14)\quad P = d + \sum_{k=0}^{p_m-1} a^k + a^{p_m-1} - n)$$

$$(15)\quad = d + \frac{a^{p_m-1}-1}{a-1} + a^{p_m-1} - n$$

The number of index pages, i, equals the number of index pages in levels 1 to $p_m - 1$ of the data base plus the number of index pages at level p_m of the data base (recall that n of the pages at level p_m will contain documents).

Response time of the computer is, therefore,

$$(16)\quad t_{rt} = 1/10\ (d + \frac{a^{p_m-1}-1}{a-1} + a^{p_m-1} - n)$$

The expected search time, ST, for a Teletext document is given by the following equation which corresponds to Equation 4 in Tech Memo BRG 79-4 (except that $\bar{p}$ has been substituted for p):

$$(17)\quad ST = \bar{p}\ (E(A) \cdot t_a + t_p) + t_p$$

which, upon substitution of $t_p = t_{rt} + t_{kp}$, is equivalent to

$$(18)\quad ST = \bar{p}\ (E(A) \cdot t_a + t_{kp} + t_{rt}) + t_{kp} + t_{rt}$$

where ST = expected total search time;

$\bar{p}$ = the average number of index pages that must be accessed to retrieve a document;

E(A) = expected number of alternatives on a page that must be searched before the target index term is found;

t_a = time required to read and process one alternative (i.e. reading rate for users),

t_p = time required to push keys and begin to display next page (i.e. broadcast Telidon response time);

t_{rt} = expected response time until target page is displayed in broadcast mode;

t_{kp} = time required to make a key press.

Note that the last two terms (i.e. $t_{kp} + t_{rt}$) in Equation 18 represent the time required to retrieve the document page while the first term on the right hand side of the same equation represents the time required to retrieve the $\overline{p}$ index pages.

For all analyses reported in this tech memo, Equation 18 was employed in making predictions and the time required to press the appropriate keys on the keypad was always assumed to be one second (i.e., $t_{kp} = 1$). Observation suggests that approximately one second is required to press the keys after an alternative has been selected from an index page. Furthermore, all predictions assume that each page in the data base requires 1/5 second to broadcast (i.e., $t_b = 1/5$ sec).

Example: What is the average amount of time required to search a broadcast Telidon data base containing 100 documents when 9 alternatives are displayed on each index page and the user employs an exhaustive search strategy while reading alternatives at the rate of one every 1/4 second?

That is, $d = 100$, $a = 9$, $t_a = 1/4$, $E(A) = a$.

The maximum number of index pages accessed is

$$p_m = \lceil \log d / \log a \rceil = \lceil 2/.95424 \rceil = \lceil 2.0959 \rceil = 3$$

The number of documents that require 2 index page retrievals to access is

$$n = \left\lfloor \frac{a^{p_m} - d}{a - 1} \right\rfloor = \left\lfloor \frac{9^3 - 100}{9 - 1} \right\rfloor = \lfloor 78.625 \rfloor = 78$$

The number of documents that require 3 index pages retrievals to access is:

$$m = d - n = 100 - 78 = 22$$

$$\overline{p} = p_m - n/d = 3 - .78 = 2.22$$

$$P = d + \frac{a^{p_m - 1} - 1}{a - 1} + a^{p_m - 1} - n$$

$$= 100 + \frac{9^2 - 1}{8} + 9^2 - 78$$

$$= 100 + 10 + 81 - 78 = 113$$

$$t_p = 1/10P + 1 = 1/10\ (113) + 1 = 12.3$$

$$ST(a=9) = \overline{p}\ (E(A) \cdot t_a + t_p) + t_p$$

$$= 2.22\ (9 \cdot 1/4 + 12.3) + 12.3$$

$$= 44.60 \text{ seconds}$$

Search time is predicted to be 44.6 seconds on the average under these conditions.

ANALYSIS B

Broadcast Telidon with VBI Transmission (Optimum As a Function of Data Base Size)

If the size of the data base (P), rather than the number of documents (d), is fixed at the outset, then the following analysis can be used to predict the optimum number of alternatives as a function of P. First, you must solve for d in terms of P.

To solve for d, start with Equation 15.

$$(15) \quad P = d + \frac{a^{p_m-1} - 1}{a - 1} + a^{p_m-1} - n$$

By substitution for n and rearrangement,

$$d = P - \left(\frac{a^{p_m-1} - 1}{a - 1}\right) - a^{p_m-1} + \left\lfloor\frac{a^{p_m} - d}{a - 1}\right\rfloor$$

Since the first 3 terms on the right hand side of this equation are integers and the fourth term is the only one that must be integerized, the operation of $\lfloor \quad \rfloor$, i.e., rounding down, can be applied to the entire right hand side of the equation.

$$d = \left\lfloor P - \frac{a^{p_m-1} - 1}{a - 1} - a^{p_m-1} + \frac{a^{p_m}}{a - 1} - \frac{d}{a - 1}\right\rfloor$$

$$d + \frac{d}{a - 1} = \left\lfloor P - \frac{a^{Pm-1} - 1}{a - 1} - a^{Pm-1} + \frac{a^{Pm}}{a - 1} \right\rfloor$$

$$\frac{(a - 1)\, d + d}{a - 1} = \left\lfloor P - \frac{a^{Pm-1} - 1}{a - 1} - a^{Pm-1} + \frac{a^{Pm}}{a - 1} \right\rfloor$$

$$ad - d + d = \left\lfloor (a - 1) \left(P - \frac{a^{Pm-1} - 1}{a - 1} - a^{Pm-1} + \frac{a^{Pm}}{a - 1} \right) \right\rfloor$$

$$d = \left\lfloor \frac{a - 1}{a} \left(P - \frac{a^{Pm-1} - 1}{a - 1} - a^{Pm-1} + \frac{a^{Pm}}{a - 1} \right) \right\rfloor$$

$$d = \left\lfloor \left(\frac{a - 1}{a} \right) P - \frac{a^{Pm-1} - 1}{a} - (a - 1)\, a^{Pm-2} + a^{Pm-1} \right\rfloor$$

$$d = \left\lfloor \left(\frac{a - 1}{a} \right) P - a^{Pm-2} + 1/a - a^{Pm-1} + a^{Pm-1} + a^{Pm-2} \right\rfloor$$

$$d = \left\lfloor \left(\frac{a - 1}{a} \right) P + \frac{1}{a} \right\rfloor$$

$$d = \left\lfloor \frac{aP - P + 1}{a} \right\rfloor \tag{19}$$

Equation 19 gives d in terms of two variables, a and P, both of which are known and fixed in any simulation. This equation was used to solve for d in generating the predictions for vertical-blanking-interval (VBI) transmission broadcast Telidon.

By rearrangement, Equation 19 can be rewritten as:

$$(20)\quad d = \left\lfloor P - \frac{1}{a}(P - 1)\right\rfloor$$

It is easy to see from Equation 20 that the number of documents equals the total number of pages in the data base minus the number of index pages. In other words,

$$(21)\quad i = \left\lfloor \frac{1}{a}(P - 1)\right\rfloor$$

The number of index pages depends only upon the number of alternatives/page and the data base size.

The maximum number of index pages that must be accessed in retrieving a document can be determined in either of two ways (assuming each document consists of only one page). First, $\underline{p}$ is the smallest value for which $d + i > P$ where $\underline{d}$, $\underline{i}$, $\underline{P}$, and $\underline{p}$ are all integer valued, $d = a^p$ and $i = \frac{a^p - 1}{a - 1}$.

Second, by the following equation:

$$(22)\quad p = \left\lceil \log \left\lfloor P - 1/a(P - 1)\right\rfloor /\log a \right\rceil$$

Equations 19, 22, and 18 were used for generating predicted search times.

ANALYSIS C

Broadcast Telidon With Full-Channel Transmission (Optimum As a Function of Data Base Size

When an entire TV channel is dedicated to broadcasting a data base, many more pages of information can be transmitted in the same period of time than when only part of a channel is used as in vertical-blanking-interval transmission (see attached memo). With only one alteration the VBI analysis can be extended to predict STs for the full-channel case. In the VBI analysis, it was assumed implicitly that each document contained precisely one page of information. For such small data bases as are likely to be transmitted via vertical blanking intervals, such an assumption will undoubtedly prove to be a relatively accurate prediction. For the much larger data bases that will probably be characteristic of full-channel transmission, the average sized document is likely to contain anywhere from 2-5 pages of information.

The VBI analysis can be extended to the full-channel case by incorporating a new variable, $\underline{f}$, the average number of frames or pages of information in a document.

If it is assumed that each document in the data base contains $\underline{f}$ frames (i.e., pages), then the previous analysis can be generalized by the following equations. First, the total number of pages in the data base equals the number of documents times the average number of pages per document plus the number of index pages. (Of course, when $f = 1$, $P = d + i$ as in Equation 11.)

$$(22) \quad P = df + i$$

$$df = P - i$$

where f = the average number of pages or frames of information in a document.

By substitution for i (see Equation 15):

$$df = \left\lfloor P - \frac{a^{Pm-1} - 1}{a - 1} - a^{Pm-1} + \frac{a^{Pm}}{a - 1} - \frac{d}{a - 1} \right\rfloor$$

$$df + \frac{d}{a - 1} = \left\lfloor P - \frac{a^{Pm-1} - 1}{a - 1} - a^{Pm-1} + \frac{a^{Pm}}{a - 1} \right\rfloor$$

$$\frac{(a - 1)\ df + d}{a - 1} = \left\lfloor P - \frac{a^{Pm-1} - 1}{a - 1} - a^{Pm-1} + \frac{a^{Pm}}{a - 1} \right\rfloor$$

$$adf - df + d = \lfloor aP - P - a^{Pm-1} + 1 - a^{Pm} + a^{Pm-1} + a^{Pm} \rfloor$$

$$d = 1/(af - f + 1) \lfloor aP - P + 1 \rfloor$$

$$(24) \quad d = \left\lfloor \frac{aP - P + 1}{af - f + 1} \right\rfloor$$

It can be seen that, by substitution of $f = 1$ (that is, by assuming that all documents are exactly 1 page long) in the last equation, the special case of d in Equation 19 is obtained.

In general, when each document contains an average of f pages, the value of p is given by:

$$(25) \quad p = \left\lceil \log \left\lfloor \frac{aP - P + 1}{af - f + 1} \right\rfloor / \log a \right\rceil$$

With appropriate evaluation of d and p by Equations 24 and 25, respectively, Equation can then be employed to generate predicted search times for the full-channel transmission case.

Waiting time, t_{rt}, until the next page is displayed equals one-half the cycle time, t_c. Cycle time is the time required to broadcast every page in the data base once.

$$(26) \quad t_{rt} = t_c/2$$

Cycle time is given by:

$$(27) \quad t_c = BP \, . \, P/EDR$$

and the effective data rate is

$$(28) \quad EDR = BL \, . \, NL \, . \, C$$

where BP = the average number of bytes of information per Telidon page (in bytes/page);

P = data base size, i.e., the number of pages in the data base (in pages);

EDR = the effective data rate (in bytes/sec), it is the average rate at which information is broadcast;

BL = the number of data (information) bytes per TV line (in bytes/TV line);

NL = the number of usable TV lines in a field (in TV lines/field);

C = the cycle rate for the fields (in fields/cycle).

Thus, cycle time is the total no. of lines of information in the data base divided by the average rate at which information is transmitted. The effective data rate depends upon the number of bytes/TV line, BL. Two data rates are considered in these analyses: BL = 16 and 24 bytes/TV line. The corresponding effective data rates are 241,920 and 362,880 bytes/sec, respectively, assuming that the average Telidon page contains approximately 600 bytes/page. Sixty fields are transmitted each second (i.e., C=60 fields/sec).

SIMULATION ASSUMPTIONS

Predicted search times were generated for each analysis based on the following assumptions and conditions.

Analyses A and B

1. Users employ either an exhaustive or a self-terminating search strategy.
2. Users read at a rate somewhere between .25 and 2 seconds per alternative.
3. The number of documents varies from 100-900 (see Table 1). OR The number of pages in the data base varies from 100-900 (see Table 2).
4. Each document contains a single page of information.
5. The effective data rate for vertical-blanking-interval transmission is 3000 bytes/second.
6. In constructing the tree, a alternatives are displayed on each index page in the data base.
7. Users do not make any errors when searching for information in the Telidon data base. (Errors would increase the expected search times.)

Analysis C

1. Users employ either an exhaustive or a self-terminating search strategy.
2. Users read at a rate somewhere between .25 and 2 seconds per alternative.
3. The size of the data base (including both index and document pages) varies between 5,000 and 15,000 pages.
4. Each document contains, on the average, somewhere between 2-5 pages of information.
5. The effective data rate for full-channel transmission is either 362,880 bytes/second (24 bytes per TV line; 252 lines per field; 60 fields/second) or 241,920 bytes/second (16 bytes per TV line).
6. In constructing the tree, a alternatives are displayed on each index page.
7. Users do not make any errors when searching for information in the Telidon data base.

RESULTS

It was not entirely clear just how many alternatives could be displayed on a single index page without impairing the user's ability to read and without making each alternative so short that its meaning becomes unclear. Presented in Figures 4 a, b, c, and d are examples of displays with 20, 40, 60, and 80 alternatives on an index page. Since many alternatives in the present Telidon data base exceed the maximum length allowed for 60 and 80 alternatives/page, it is unlikely that any information provider would ever use more than 40 alternatives/page. Therefore, the number of alternatives/page was varied between 2 and 40 in generating predictions from these three analyses.

Analysis A

In deriving the predictions presented in Table 1 and Figures 1-3, the number of document pages in the data base was systematically varied from 100 to 300 to 500 to 900. In all cases the size of the corresponding data base must be larger than the number of documents because the data base includes both index and document pages. Thus, when the number of documents equals 100 and the number of alternatives per page is 10, the number of pages in the data base is 111 (i.e. P = d + i).

The optimum number of alternatives for different user search strategies, reading rates, and numbers of documents is displayed in Table 1. From this table it can be seen that, for the conditions considered, the optimum is always 10 or more alternatives per index page. This result contrasts sharply with that found for interactive Telidon where the optimum was always 10 or less. This difference in optimums for interactive and broadcast Telidon is attributable (a) to the much longer system response times for broadcast Telidon (10-90 seconds for broadcast Telidon compared to 1/2 - 1 1/2 seconds for Telidon) and (b) the much smaller broadcast Telidon data bases.

Predicted search times are presented in Figures 2 and 3 for varying numbers of documents (assumes VBI transmission). It can be seen that search times are minimized for intermediate values of a, the number of altnatives/page. Too few or too many alternatives/page produce [illegible] longer search times. The slowest search times occur when only 2 alternatives are displayed on each index page. For 2 alternatives/page the search times are 2 1/2 to 6 1/2 times as long as the optimum!

The optimum number of alternatives/page is always 10 or greater for data bases containing 100 or more document pages (see Table 1). However, unlike interactive Telidon, the optimum depends on the number of documents in the data base. The optimum increases as the number of document pages in the data base increases (see Figure 1).

If the number of alternatives/page is limited to a maximum of 10, then the expected search time will be slower than optimal. Provided that the optimum between 2-10 alternatives/page is used, search times can be kept to less than 41% slower than the overall optimum. In most cases, the local optimum between 2 and 10 is 10 alternatives/page. If fewer than 10 alternatives are displayed per page, then search times will be considerably slower than the optimum. Thus, as many alternatives as possible should be displayed on each index page. That is, as close to 10 alternatives as possible should be displayed oneach page.

Regardless of whether there is or is not a limit on the number of alternatives/page, no fewer than 6 alternatives should be displayed. Search times become inordinately long when 2-5 alternatives appear on each index page. For 100 document pages, search times for 6 or more alternatives will not be more than 25% slower than the optimum. For 300 document pages, search times for 6 or more alternatives will not be more than 70% slower than optimum.

Data bases containing more than 300 document pages will probably require more time to search and retrieve target information than most people would be willing to spend. Search times would probably average anywhere from 3 to 7 minutes! (See Figures 2 and 3.) For a small data base with only 100 document pages, predicted search times range between 35 and 90 seconds (provided that somewhere between 5 to 10 alternatives are displayed on each page); see Figures 2a and 3a. For 300 document pages, search times should range between 100 and 175 seconds (provided that between 15 and 20 alternatives are displayed on each page); see Figures 2b and 3b.

Analysis B

Predicted optimums for varying sizes of data bases (assuming VBI transmission) are presented in Table 2. These results are similar to those generated from Analysis A in that the optimum number of alternatives per page is 10 or greater for almost any condition. From Table 2, it can be seen that the optimum does not vary either with user search strategy or with reading rate. It does vary directly, however, with the size of data base; increasing the size of the data base increases the optimum number of alternatives per page. Predicted search time is plotted as a function of the number of alternatives/page in Figures 6 and 7.

Analysis C

Predicted optimums for varying sizes of data bases (assuming full-channel transmission) are presented in Tables 3 and 4. User search strategy does not affect the optimum very much. The optimum is lower for faster readers than it is for slower readers. Increasing the size of the data base increases the optimum number of alternatives per page. Increasing the average number of pages per document decreases the optimum. Increasing the effective data rate from 241,920 to 362,880 bytes/second has very little effect on the optimum. The optimum is neither consistently over nor under 10 alternatives per index page. Predicted search times are presented in Tables 5a through h for what is assumed to be a typical Telidon user (i.e., a reading rate of 1 sec/alternative is assumed).

Table 5 presents the range of expected search times within which actual search times should occur for different sized data bases and different rates of data transmission. Increases in the size of data base appears to increase STs linearly. The higher data rate of 362,880 bytes/sec reduces search time but not by that much (i.e., a 50% increase in the rate of data transmission results in only a 10 - 25% reduction in ST). In most cases, STs are in the order of 1-2 minutes. On the face of it, this appears to be an acceptable range of STs but only empirical research can answer the question definitively.

Search times are exceedingly long when compared with the optimum for fewer than 6 alternatives/page. For example, search times with 2 alternatives/page range anywhere from 30 to 300% longer than the optimum. Increasing the number of alternatives/page can reduce search times significantly, although even for as many as 5 alternatives/page can lengthen search time by 56% over the optimum.

Limiting the number of alternatives displayed per page to a maximum of 10 can increase search time up to 21% above the optimal. Under most of the conditions considered, however, search times for 10 or fewer alternatives/page are within 10% of the optimal.

Figures 5a to 5h display the relationship between search time and the number of alternatives/page for the average reader . Figures 6-17 display the relationship between search time and the number of alternatives/ page for both the slowest and fastest readers. Thus, in Figures 6-17 the predicted search times of all readers should fall somewhere between the two exterior function curves on the graph .

DISCUSSION

A keypad would be most useful if the optimum was always 10 or fewer alternatives/page for then the numeric, rather than an alphabetic, coding scheme could be used for index pages. Since the optimum sometimes exceeds 10 for full-channel transmission, a keyboard with alphabetic capability appears necessary. There are, however, two powerful alternatives, either of which would permit the retention of the keypad. First, the numeric keypad could be retained, if each alternative on a page was assigned a two-digit code name (see Figure 4). When document page numbering depends upon the numbering of pages, doubling the number of digits assigned to each alternative essentially doubles the number of digits required for coding each document page. While doubling the number of digits would probably be a real problem for very large data bases such as interactive Telidon (for example, a 16 level tree would require an unwieldy 32-digit number for each document page), doubling will probably have only a relatively small effect on small data bases characteristic of broadcast Telidon with VBI transmission (where only 2-4 index pages, i.e., 4-8 digits, would be required to access a given document). For relatively small data bases that are likely to be made available on broadcast Telidon with VBI transmission (i.e. 100-1000 pages), doubling the number of digits will probably have very little effect on the user (because a document could still be accessed directly with only 4 - 8 digits). Moreover, if there are fewer than 100 documents in a data base, then the optimum number of alternatives per page will be less than 10 for most conditions. In this case there is no question that a numeric keypad would be satisfactory.

Second, the number of alternatives displayed per page could be limited to a maximum of 10. This is a particularly attractive alternative in the case of full-channel transmission because search times will, at worst, be no more than 21% longer for a maximum of 10 alternatives/ page than for the optimum. Moreover, under most conditions, search times will be no more than 10% longer than optimum.

Limiting the number of alternatives/page to 10, then, is highly recommended as the solution for maintaining a numeric keypad for broadcast Telidon with full-channel transmission. Unfortunately, no clear recommendation can be made for the case of VBI transmission. Search times for a maximum of 10 alternatives/page are, in some cases, moderately (over 50%) longer than the optimum. Moreover, the optimum is always 10 or more for any data base containing 100 or more document pages. The choice between double-digit coding and setting a maximum is a difficult one. Empirical work may be necessary to assess more accurately the impacts of these two strategies.

From Figures 2 and 3, it can be seen that, for a very small data base containing about 100 documents, the search times are not likely to be considered overlong by the broadcast Telidon user (most people would probably require between 2/3 and 1 1/3 minutes provided that the optimum number of alternatives was presented on each index page). For a data base containing 300 documents, users would probably require 2-3 minutes to find target information through the tree. It is not clear whether users would tolerate spending several minutes searching for information. However, for the 2 larger data bases of 500 and 900 document pages, the optimum search times are in the order of 3-4 1/2 and 5 - 7 minutes! Probably not too many people would tolerate such long delays in locating information on Telidon. Empirical research is required to determine just how much time they are willing to spend searching.

In contrast to search time for interactive Telidon, search time for broadcast (VBI) Telidon varies with the size of data base. Broadcast Telidon search time varies with the size of data base because broadcast response time (denoted t_{rt}) depends directly upon the size of data base. Interactive Telidon search time does not vary with data base size because computer response time does not depend upon data base size.

TABLE 1

OPTIMUM NUMBER OF ALTERNATIVES ON AN INDEX PAGE

FOR BROADCAST TELIDON WITH VBI TRANSMISSION[a] (ANALYSIS A)

USER SEARCH STRATEGY	READING TIME PER ALTERNATIVE	NO. OF DOCUMENT PAGES IN DATA BASE[b]			
		100	300	500	900
EXHAUSTIVE	.25 sec	11 (10-21)	21 (18-27)	26 (23-33)	32 (32-40)
	.50	10 (10-11)	18 (18-20)	23 (23-25)	30 (30-32)
	1.00	10 (10)	18 (17-18)	23 (23)	30 (30)
	2.00	10 (10)	17 (17-18)	22 (22-23)	30 (30)
SELF-TERMINATING	.25 sec	26 (13-40)	31 (22-40)	40 (28-40)	39 (34-40)
	.50	11 (10-21)	21 (18-27)	26 (23-33)	32 (30-40)
	1.00	10 (10-11)	18 (18-20)	23 (23-25)	30 (30-32)
	2.00	10 (10)	18 (17-18)	23 (23)	30 (30)

---

[a] The optimum for broadcast Telidon unlike that for interactive Telidon, varies with changes in the size of the data base (i.e. the total number of documents).

[b] Table entries represent the optimum number of alternatives for the specified conditions. In parentheses below each optimum is given the range of the number of alternatives for which total search time is within 1 second of that optimum. Thus, when the optimum is 11 alternatives per page, any number of alternatives per page could be used between 10 and 21 without increasing search time by more than one second.

TABLE 2

OPTIMUM NUMBER OF ALTERNATIVES ON AN INDEX PAGE FOR BROADCAST TELIDON WITH VERTICAL-BLANKING-INTERVAL TRANSMISSION (ANALYSIS B)

USER SEARCH STRATEGY	READING TIME PER ALTERNATIVE	NO. OF PAGES IN DATA BASE			
		100	300	500	900
EXHAUSTIVE	.25 sec	10	17	22	30
	.50	10	17	22	30
	1.00	10	17	22	30
	2.00	9	17	22	30
SELF-TERMINATING	.25 sec	12	17	22	30
	.50	10	17	22	30
	1.00	10	17	22	30
	2.00	10	17	22	30

TABLE 3

OPTIMUM NUMBER OF ALTERNATIVES ON AN INDEX PAGE FOR BROADCAST TELIDON WITH FULL-CHANNEL TRANSMISSION AT A RATE OF 241,920 BYTES/SECOND[a] (ANALYSIS C)

USER SEARCH STRATEGY	READING TIME PER ALTERNATIVE	AVERAGE NO. OF PAGES PER DOCUMENT	NO. OF PAGES IN DATA BASE		
			5000	10000	15000
EXHAUSTIVE	.25 sec	2	14	17	20
		5	10	13	15
	.50	2	13	17	20
		5	10	13	15
	1.00	2	7	9	9
		5	10	13	14
	2.00	2	5	8	9
		5	6	7	8
SELF-TERMINATING	.25 sec	2	14	17	20
		5	32	40	40
	.50	2	14	17	20
		5	10	13	15
	1.00	2	7	17	20
		5	10	13	15
	2.00	2	7	9	9
		5	6	13	14

[a] Assumes 16 data-bytes per TV line for an effective data rate equal to 241,920 bytes/second.

TABLE 4

OPTIMUM NUMBER OF ALTERNATIVES ON AN INDEX PAGE FOR BROADCAST TELIDON WITH FULL-CHANNEL TRANSMISSION[a] AT A RATE OF 362,880 BYTES/SECOND (ANALYSIS C)

USER SEARCH STRATEGY	READING TIME PER ALTERNATIVE	AVERAGE NO. OF PAGES PER DOCUMENT	NO. OF PAGES IN DATA BASE		
			5000	10000	15000
EXHAUSTIVE	.25 sec	2	14	17	20
		5	10	13	15
	.50	2	7	17	20
		5	10	13	15
	1.00	2	7	8	9
		5	6	7	14
	2.00	2	5	6	6
		5	4	7	7
SELF-TERMINATING	.25 sec	2	14	17	20
		5	32	40	40
	.50	2	14	17	20
		5	10	13	15
	1.00	2	7	17	20
		5	10	13	15
	2.00	2	7	8	9
		5	6	7	8

---

[a] Assumes 24 data-bytes per TV line for an effective data rate equal to 362,880 bytes/second.

TABLE 5

PREDICTED SEARCH TIMES FOR BROADCAST TELIDON WITH FULL-CHANNEL TRANSMISSION

EFFECTIVE DATA RATE[a]	DATA BASE SIZE[b]	PREDICTED SEARCH TIME[c]	PREDICTED SEARCH TIMES ($a \leq 10$)[d]
241,920	5,000	30- 91	33- 91
	10,000	54-135	65-135
	15,000	81-173	97-173
362,880	5,000	23- 79	24- 79
	10,000	41-113	47-113
	15,000	59-140	68-140

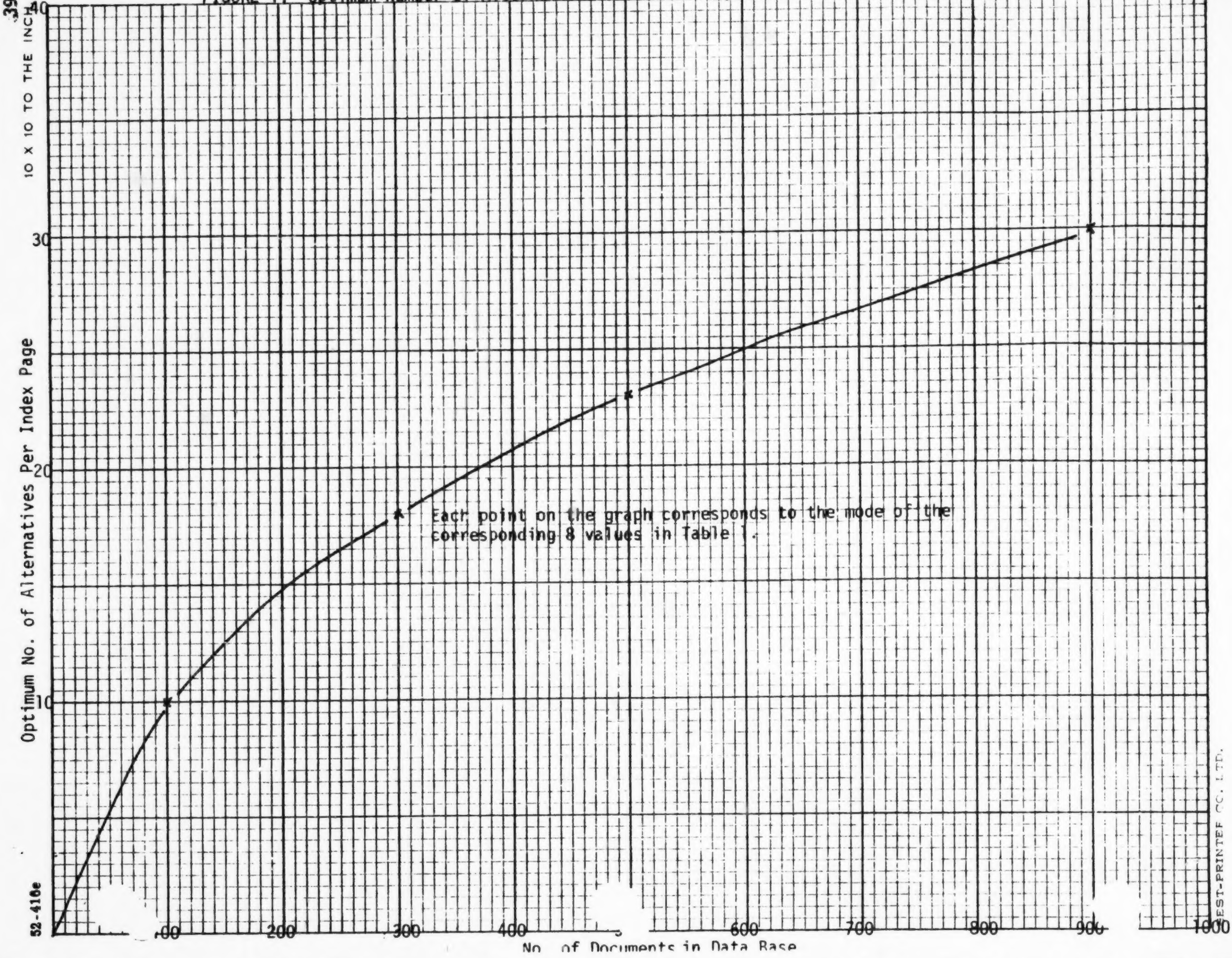
[a] Measured in bytes/second. The effective data rate is the rate at which information is broadcast over a TV channel. It equals the product of (a) BL, the number of data-bytes per TV line, (b) NL, the number of usable TV lines in a field, and (c) C, the cycle rate in fields/sec. For a full-channel, $NL = 252$ usable TV lines, and $C = 60$ fields/sec. For $BL = 16$, the effective data rate $= BL \times NL \times C = 241{,}920$ bytes/sec. For $BL = 24$, the effective data rate $= 362{,}880$ bytes/sec.

[b] The total number of pages in the data base including both index and document pages.

[c] Measured in seconds. The search times presented represent the range of optimal STs.

[d] Measured in seconds. The search times reported represent the range of search times which are (locally) optimum given that the number of alternatives/page is limited to a maximum of 10.

FIGURE 1: Optimum Number of Alternatives Per Index Page as a Function of Size of Broadcast Telidon Data Base.



Each point on the graph corresponds to the mode of the corresponding 8 values in Table 1.

FIGURE 2a: Search Time As a Function of the Number of Alternatives Per Index Page (for 100 document pages)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA
GA-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

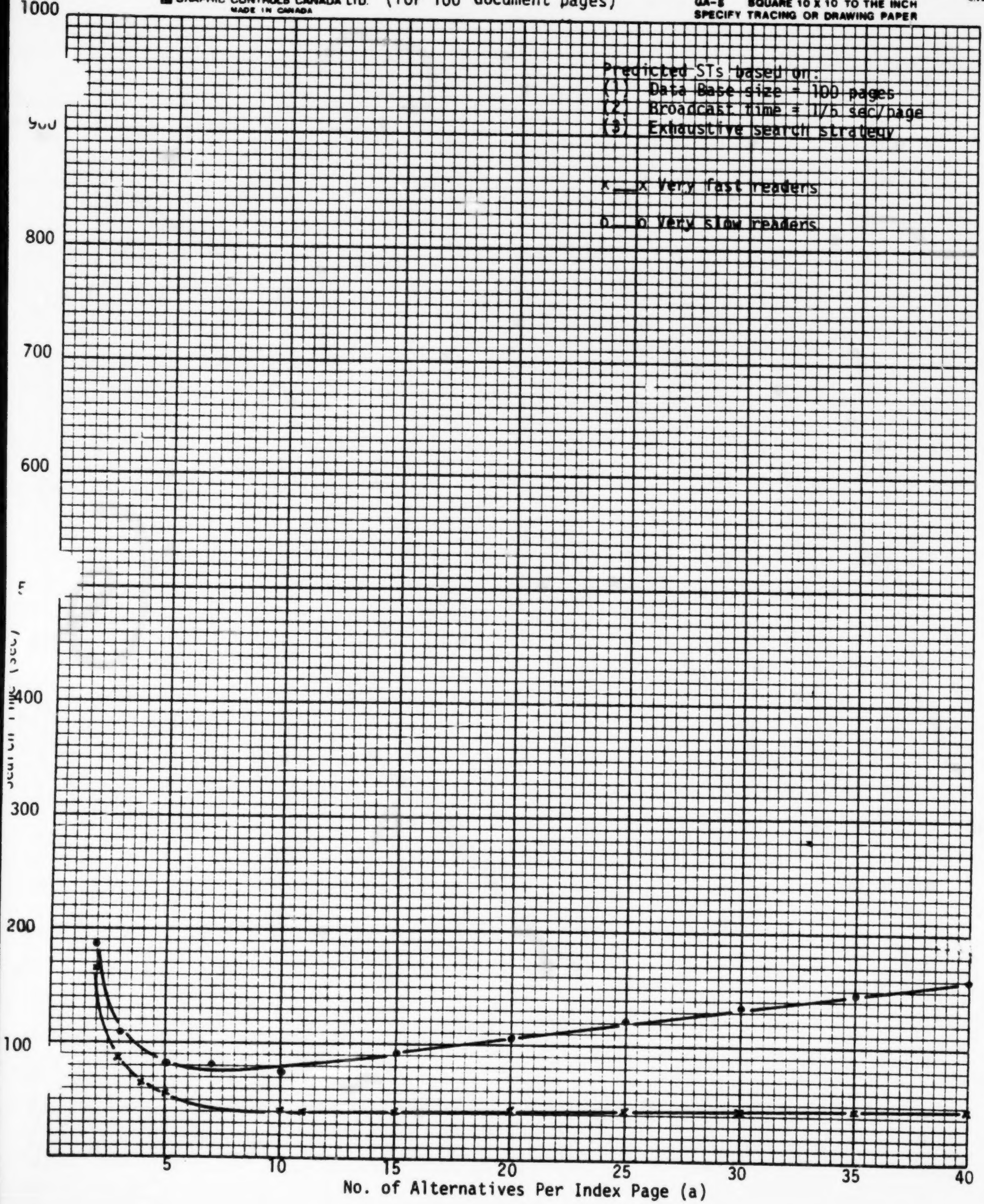


FIGURE 2b: Search Time As a Function of the Number of Alternatives Per Index Page (for 300 document pages)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA
GA-8 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

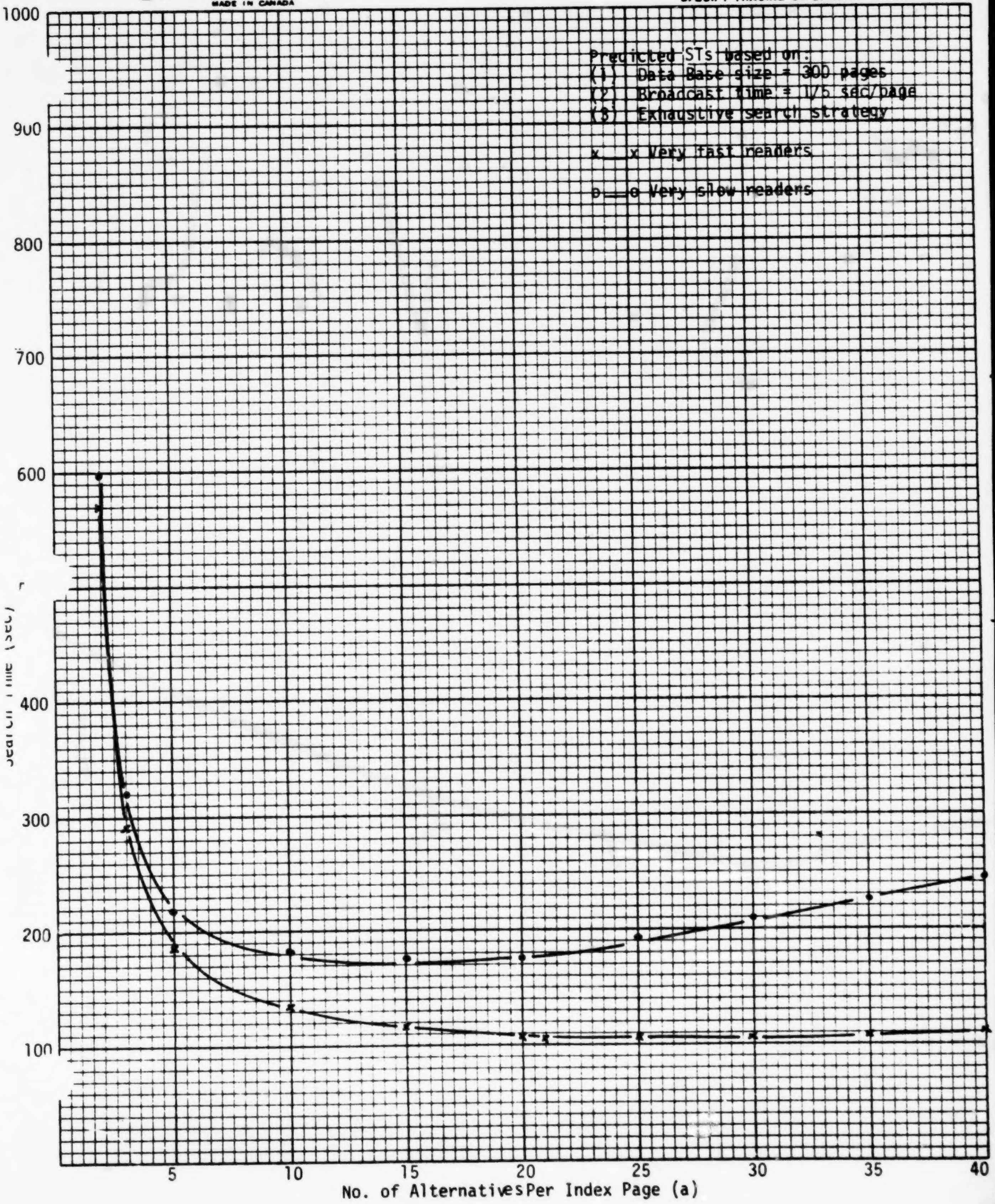


FIGURE 2c: Search Time As a Function of the Number of Alternatives Per Index Page (for 500 document pages)

GRAPHIC CONTROLS CANADA LTD. MADE IN CANADA
GA-5 SQUARE 10 X 10 TO THE INCH SPECIFY TRACING OR DRAWING PAPER

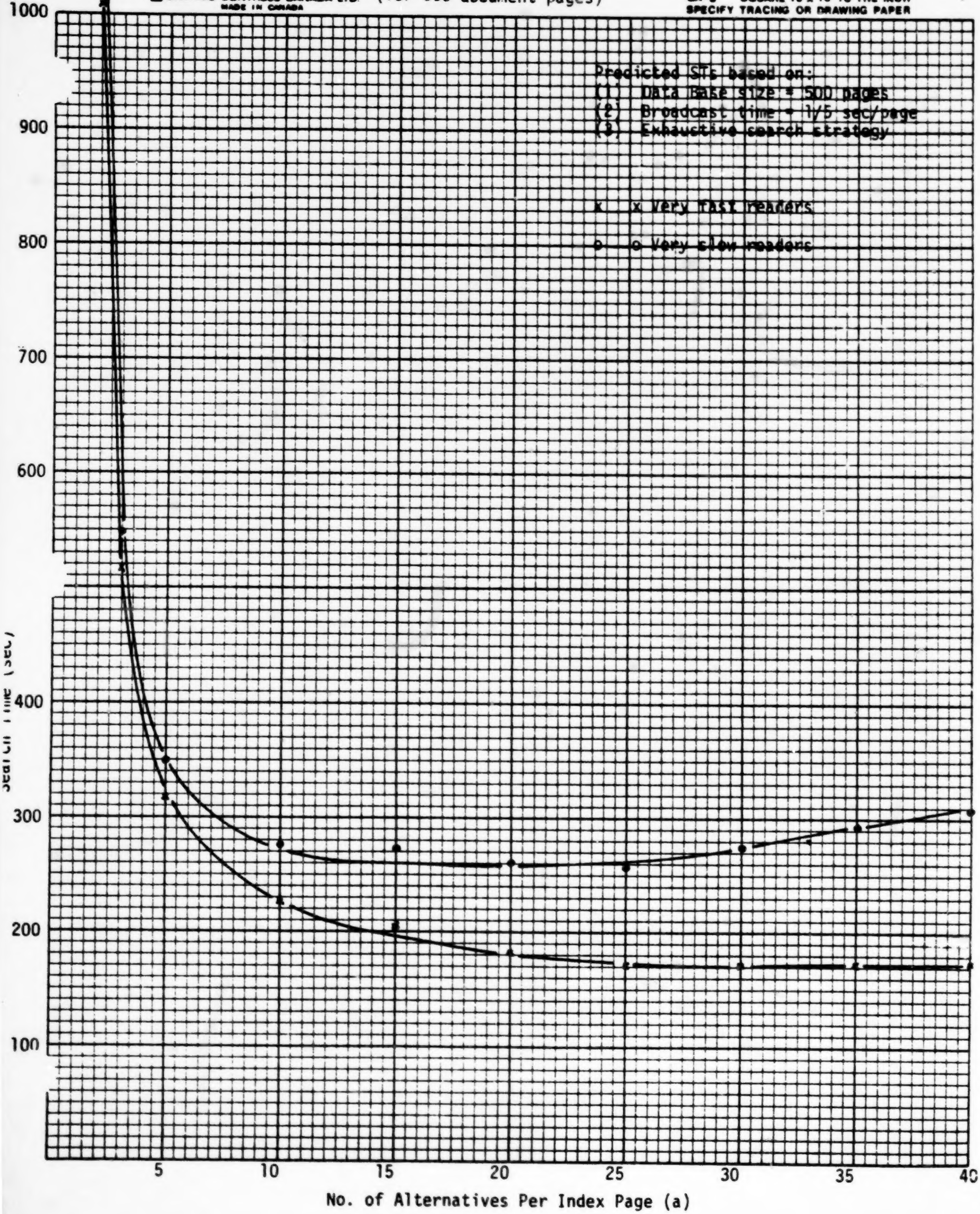


FIGURE 2d: Search Time As a Function of the Number of Alternatives Per Index Page (for 900 document pages)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA

GA-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

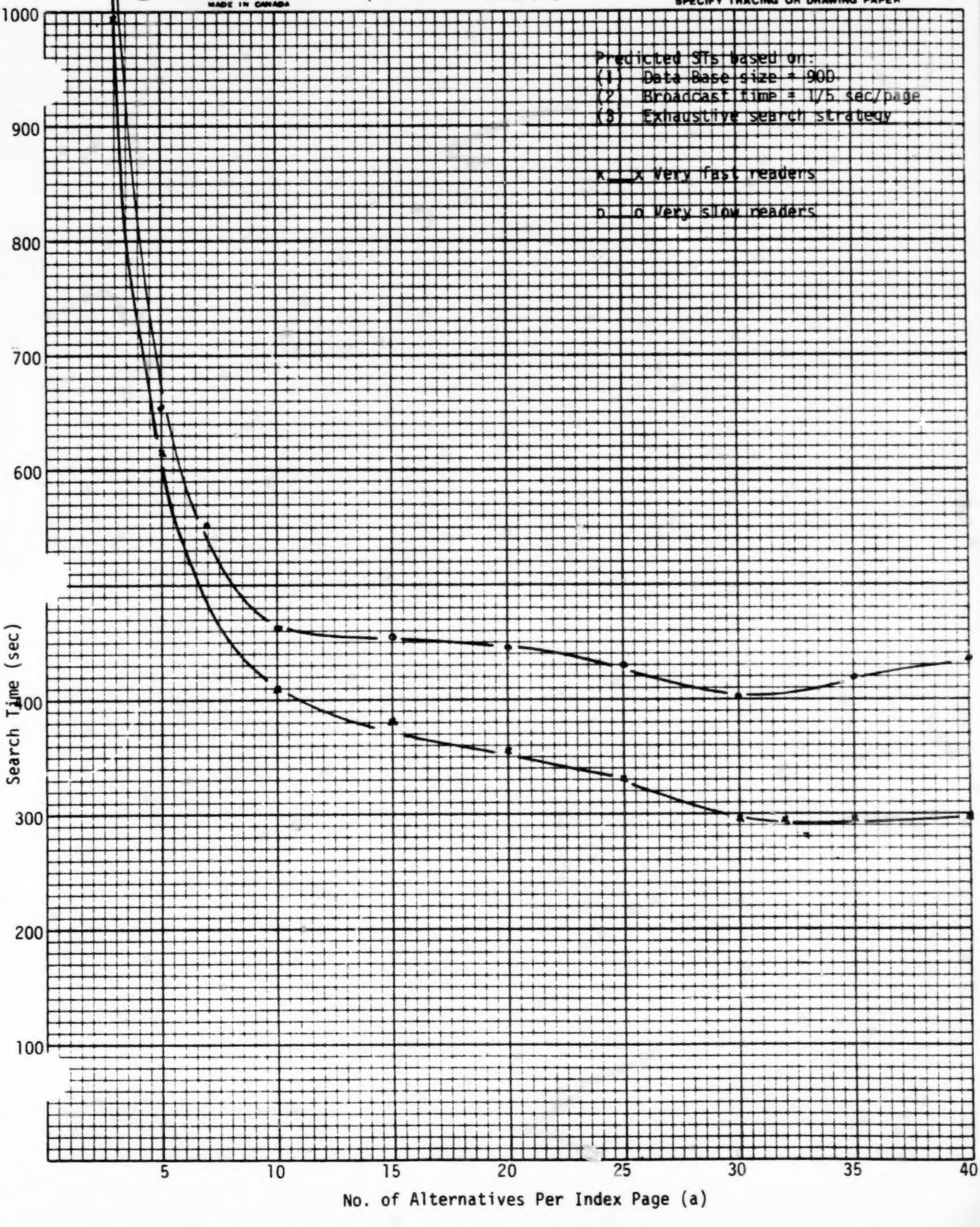


FIGURE 3a: Search Time As a Function of the Number of Alternatives Per Index Page (for 100 document pages)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA
SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

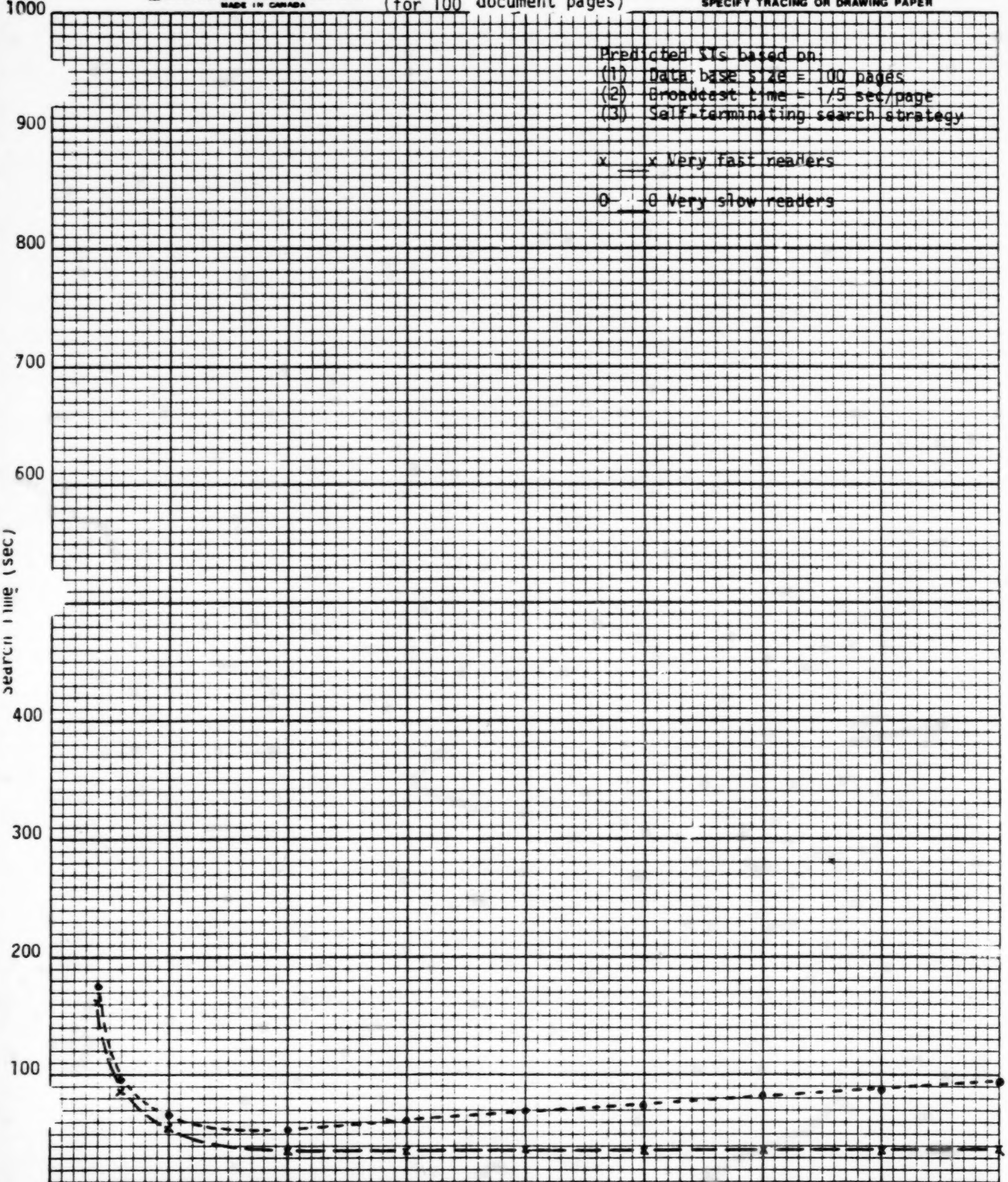


FIGURE 3b: Search Time As a Function of the Number of Alternatives Per Index Page (for 300 document pages)

GRAPHIC CONTROLS CANADA LTD. MADE IN CANADA
GA-5 SQUARE 10 X 10 TO THE INCH SPECIFY TRACING OR DRAWING PAPER

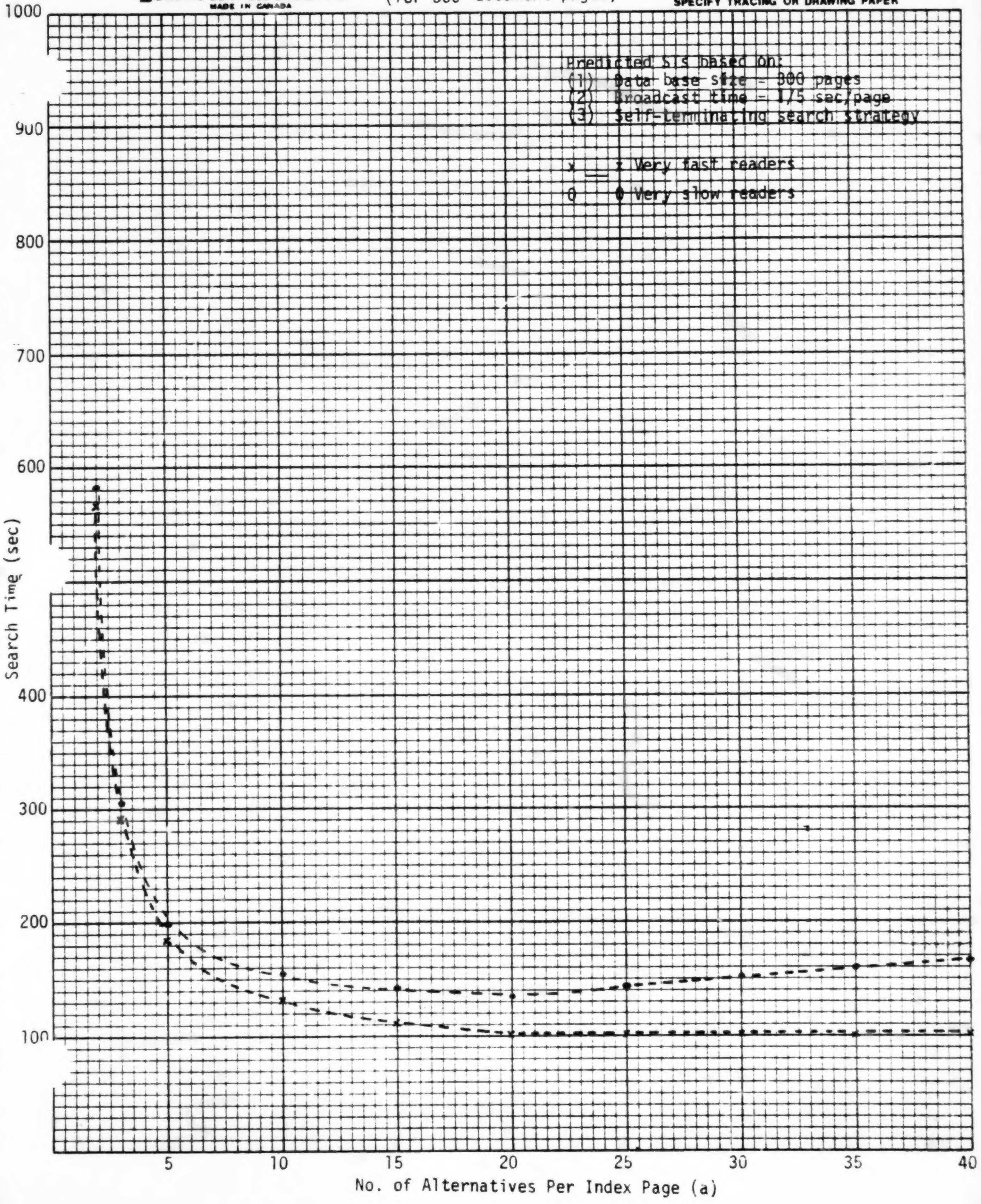


FIGURE 3c: Search Time As a Function of the Number of Alternatives Per Index Page (for 500 document pages)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA
QA-8 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

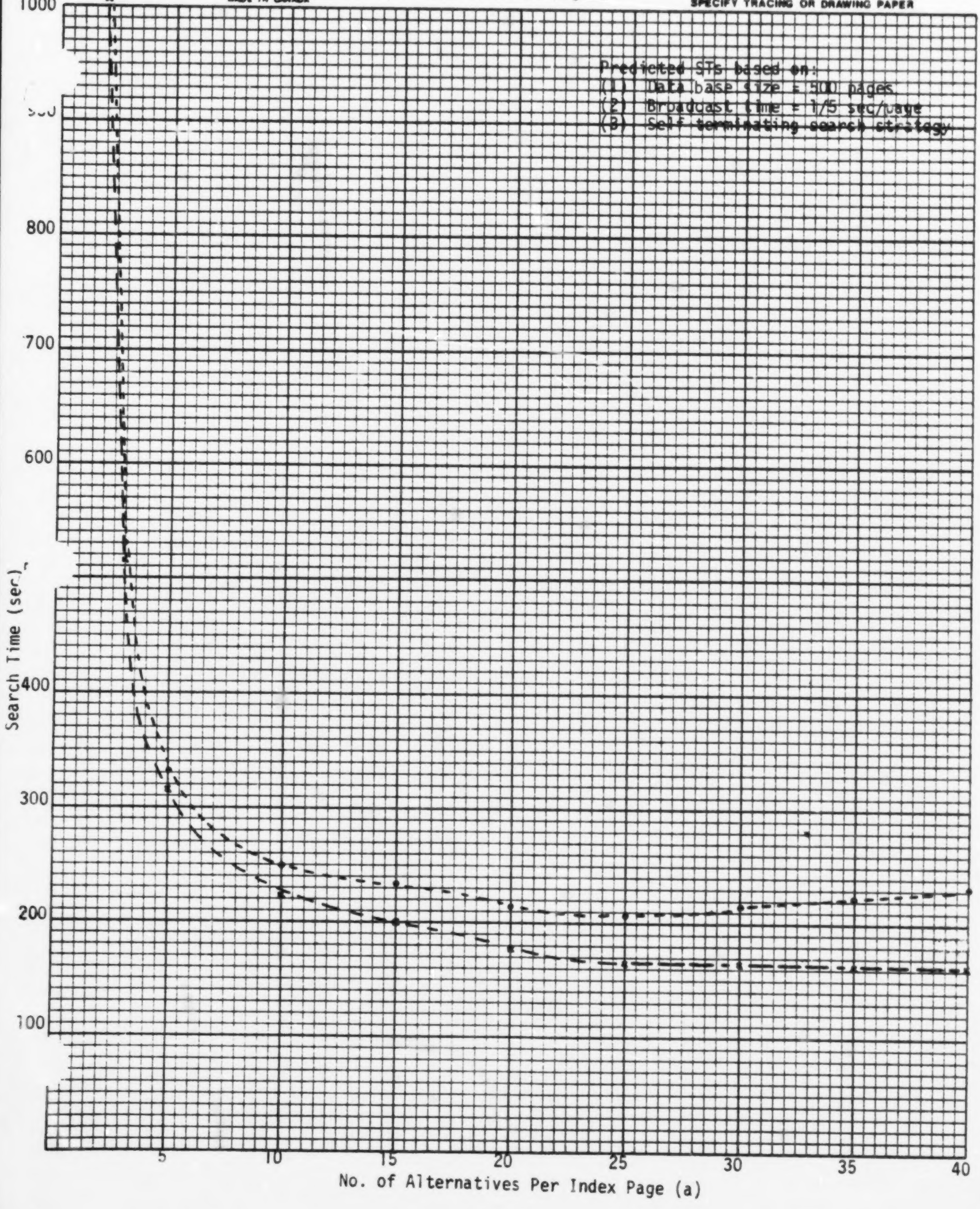


FIGURE 3d: Search Time As a Function of the Number of Alternatives Per Index Page (for 900 document pages)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA
GA-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

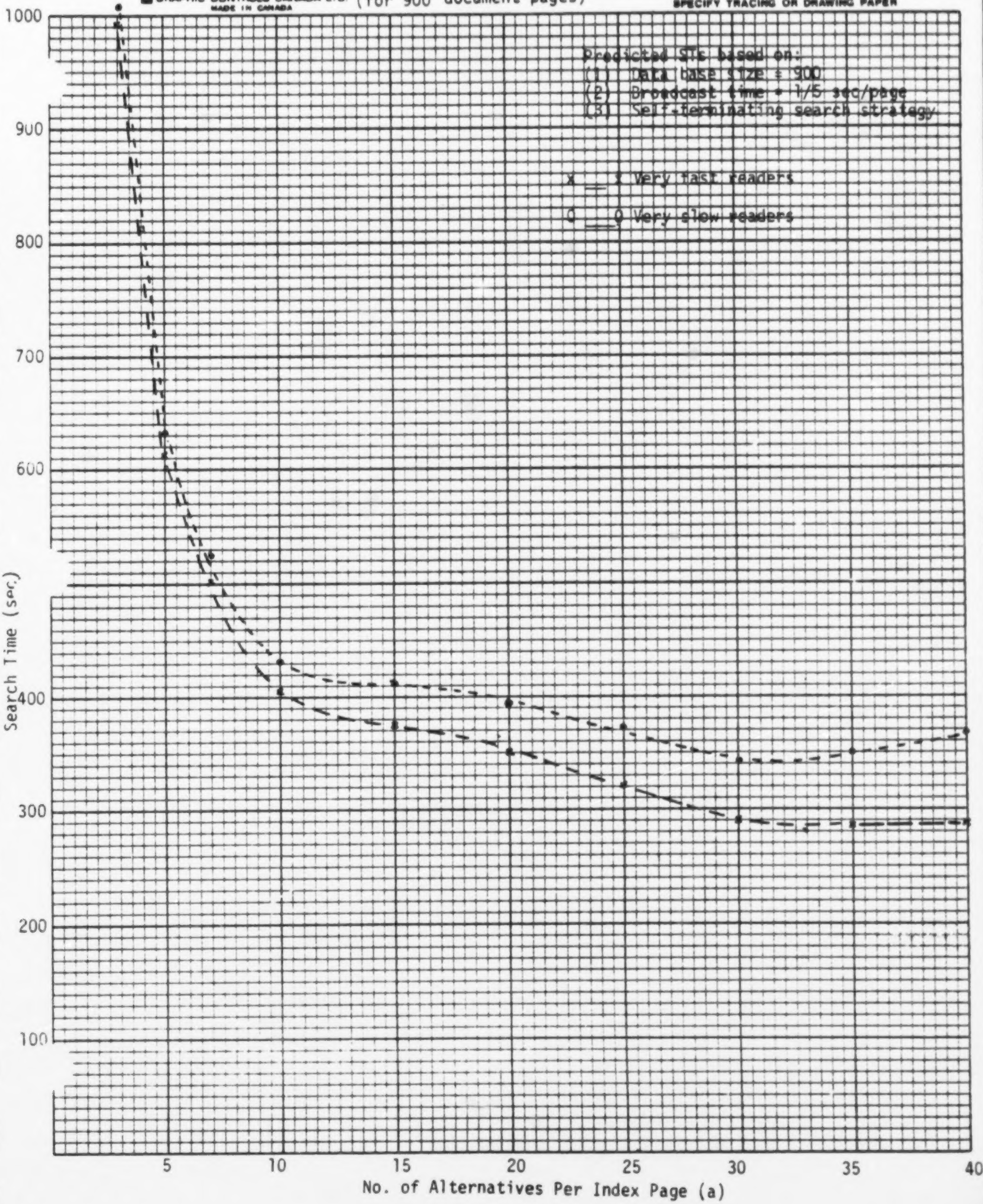
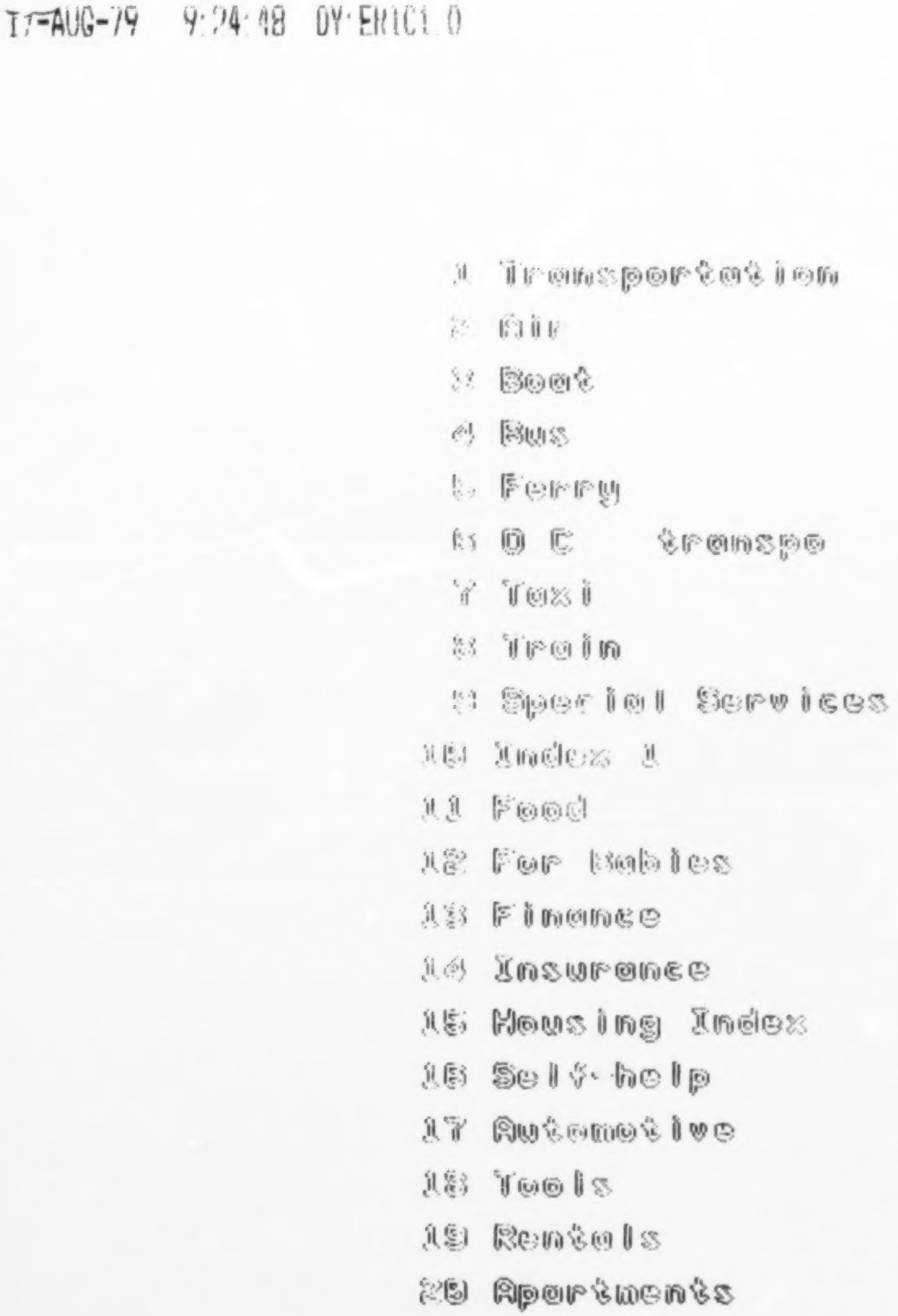


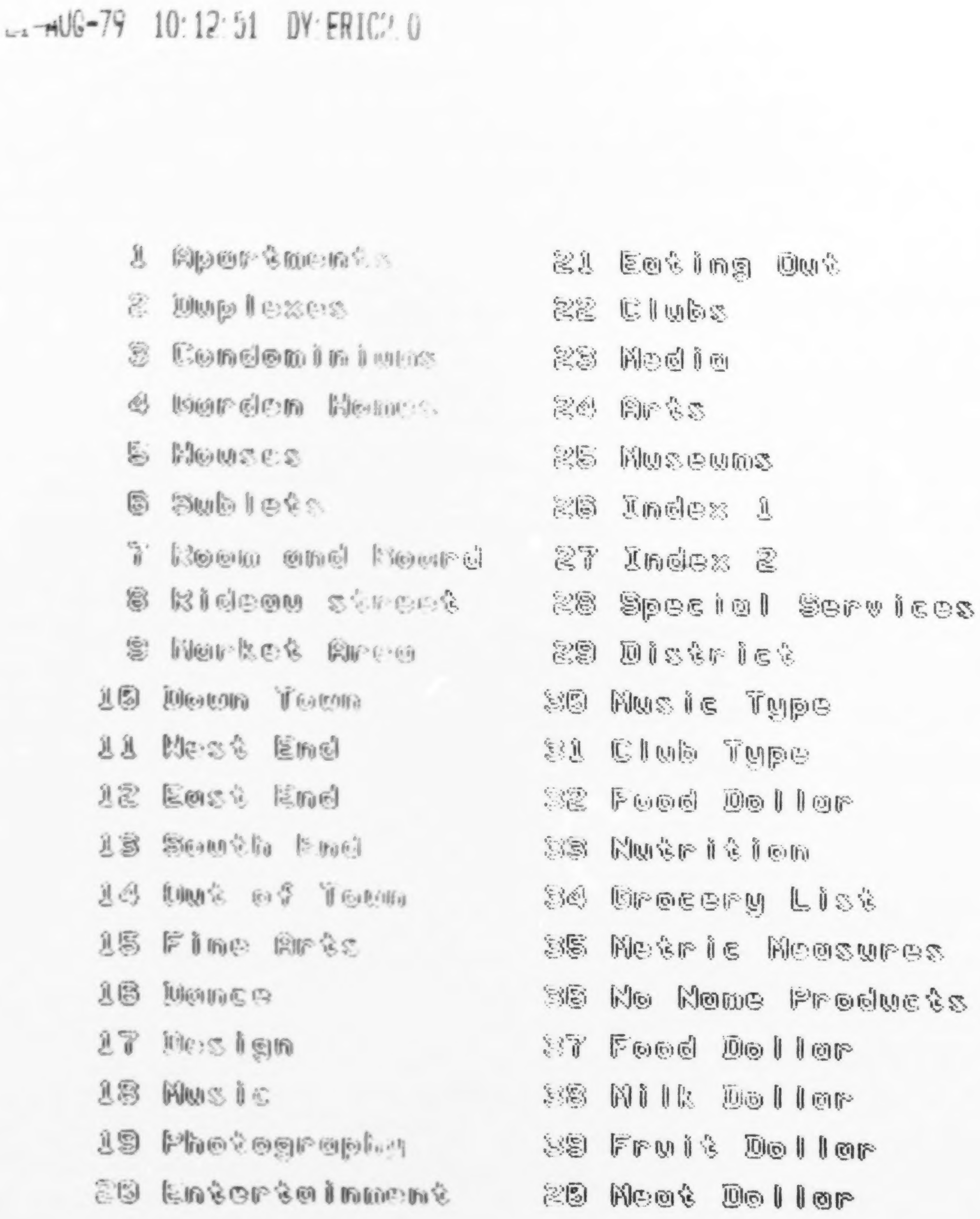
FIGURE 4a: Example of a Telidon Index Page With 20 Alternatives Displayed



17-AUG-79 9:24:48 DY:ERIC1.0

1 Transportation
2 Air
3 Boat
4 Bus
5 Ferry
6 O C transpo
7 Taxi
8 Train
9 Special Services
10 Index 1
11 Food
12 For babies
13 Finance
14 Insurance
15 Housing Index
16 Self-help
17 Automotive
18 Tools
19 Rentals
20 Apartments

FIGURE 4b: Example of a Telidon Page With 40 Alternatives Displayed

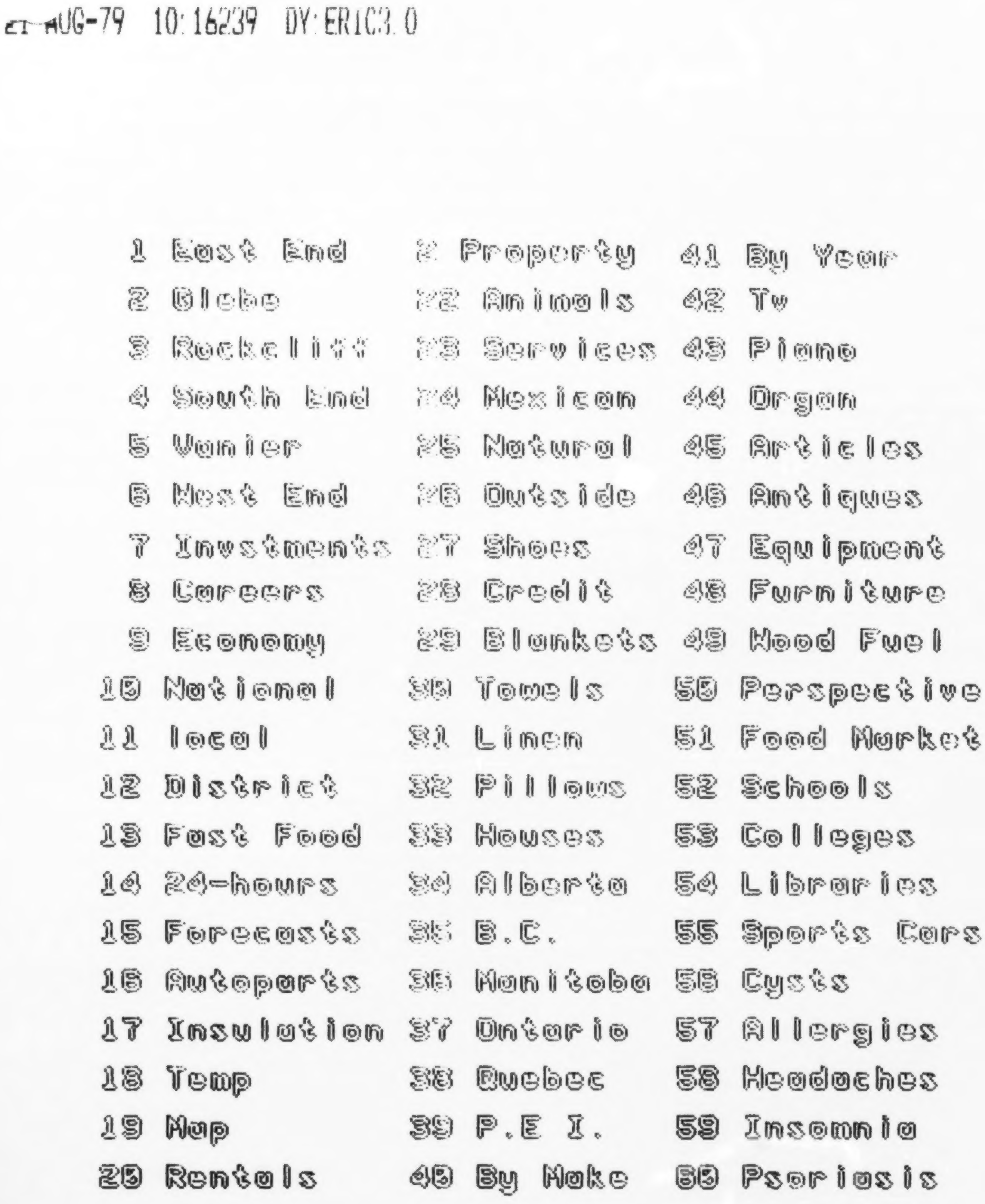


-AUG-79 10:12:51 DY:ERIC2.0

1 Apartments
2 Duplexes
3 Condominiums
4 Garden Homes
5 Houses
6 Sublets
7 Room and Board
8 Rideau street
9 Market Area
10 Down Town
11 West End
12 East End
13 South End
14 Out of Town
15 Fine Arts
16 Dance
17 Design
18 Music
19 Photography
20 Entertainment

21 Eating Out
22 Clubs
23 Media
24 Arts
25 Museums
26 Index 1
27 Index 2
28 Special Services
29 District
30 Music Type
31 Club Type
32 Food Dollar
33 Nutrition
34 Grocery List
35 Metric Measures
36 No Name Products
37 Food Dollar
38 Milk Dollar
39 Fruit Dollar
20 Meat Dollar

FIGURE 4c: Example of a Telidon Page With 60 Alternatives Displayed



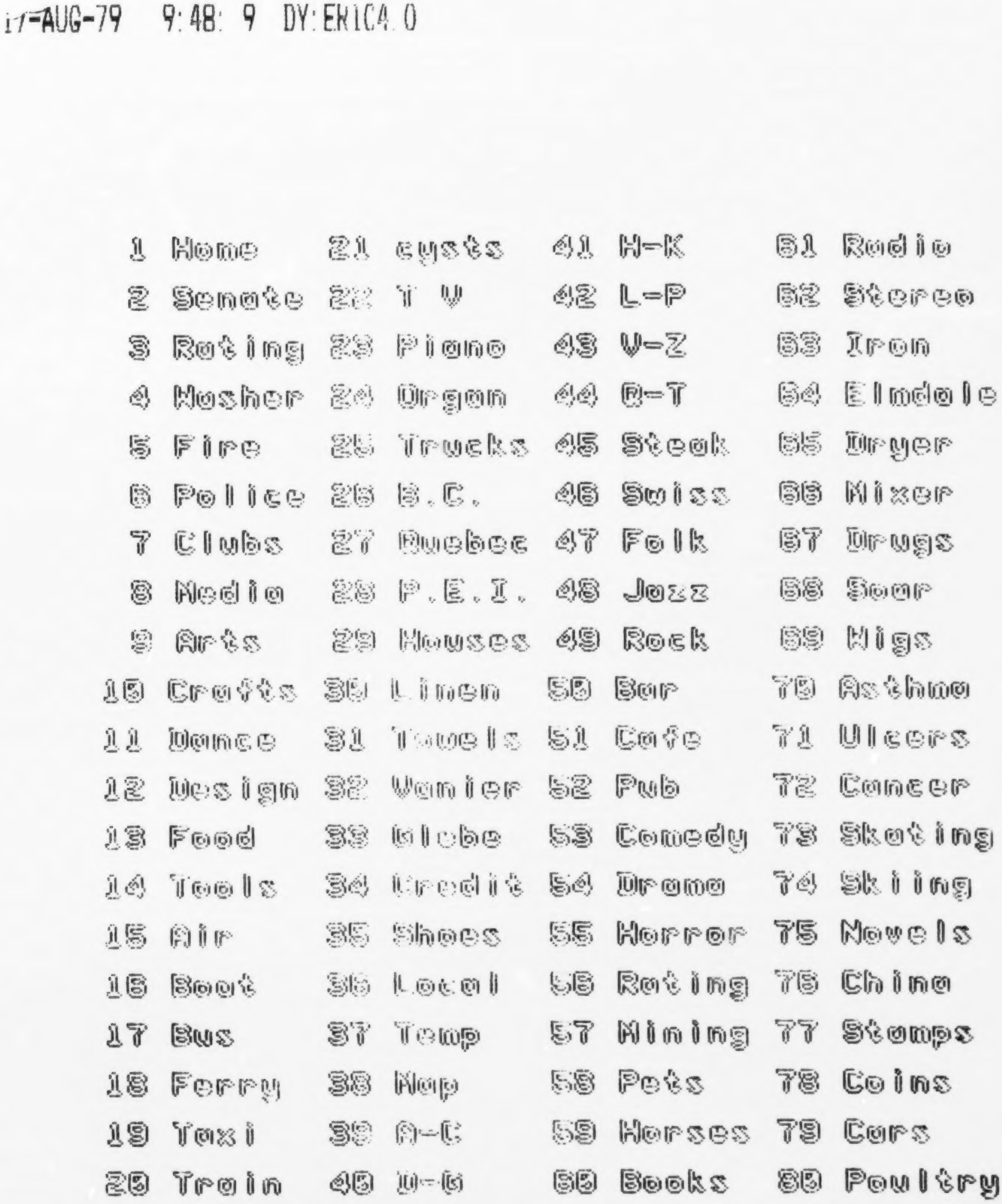
21-AUG-79 10:16239 DY:ERIC3.0

1 East End
2 Glebe
3 Rockcliff
4 South End
5 Vanier
6 West End
7 Investments
8 Careers
9 Economy
10 National
11 local
12 District
13 Fast Food
14 24-hours
15 Forecasts
16 Autoparts
17 Insulation
18 Temp
19 Map
20 Rentals

2 Property
22 Animals
23 Services
24 Mexican
25 Natural
26 Outside
27 Shoes
28 Credit
29 Blankets
30 Towels
31 Linen
32 Pillows
33 Houses
34 Alberta
35 B.C.
36 Manitoba
37 Ontario
38 Quebec
39 P.E.I.
40 By Make

41 By Year
42 Tv
43 Piano
44 Organ
45 Articles
46 Antiques
47 Equipment
48 Furniture
49 Wood Fuel
50 Perspective
51 Food Market
52 Schools
53 Colleges
54 Libraries
55 Sports Cars
56 Cysts
57 Allergies
58 Headaches
59 Insomnia
60 Psoriasis

FIGURE 4d: Example of a Telidon Page With 80 Alternatives Displayed



```
17-AUG-79   9:48: 9  DY:ERICA.0

 1 Home     21 cysts    41 H-K      61 Radio
 2 Senate   22 T V      42 L-P      62 Stereo
 3 Rating   23 Piano    43 V-Z      63 Iron
 4 Kosher   24 Organ    44 Q-T      64 Elmdale
 5 Fire     25 Trucks   45 Steak    65 Dryer
 6 Police   26 B.C.     46 Swiss    66 Mixer
 7 Clubs    27 Quebec   47 Folk     67 Drugs
 8 Media    28 P.E.I.   48 Jazz     68 Soap
 9 Arts     29 Houses   49 Rock     69 Wigs
10 Crafts   30 Linen    50 Bar      70 Asthma
11 Dance    31 Towels   51 Cafe     71 Ulcers
12 Design   32 Vanier   52 Pub      72 Cancer
13 Food     33 Globe    53 Comedy   73 Skating
14 Tools    34 Credit   54 Drama    74 Skiing
15 Air      35 Shoes    55 Horror   75 Novels
16 Boat     36 Local    56 Rating   76 China
17 Bus      37 Temp     57 Mining   77 Stamps
18 Ferry    38 Map      58 Pets     78 Coins
19 Taxi     39 A-C      59 Horses   79 Cars
20 Train    40 D-G      60 Books    80 Poultry
```

FIGURE 5a: Search Time As a Function of the Number of Alternatives Per Page (Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD
MADE IN CANADA
10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

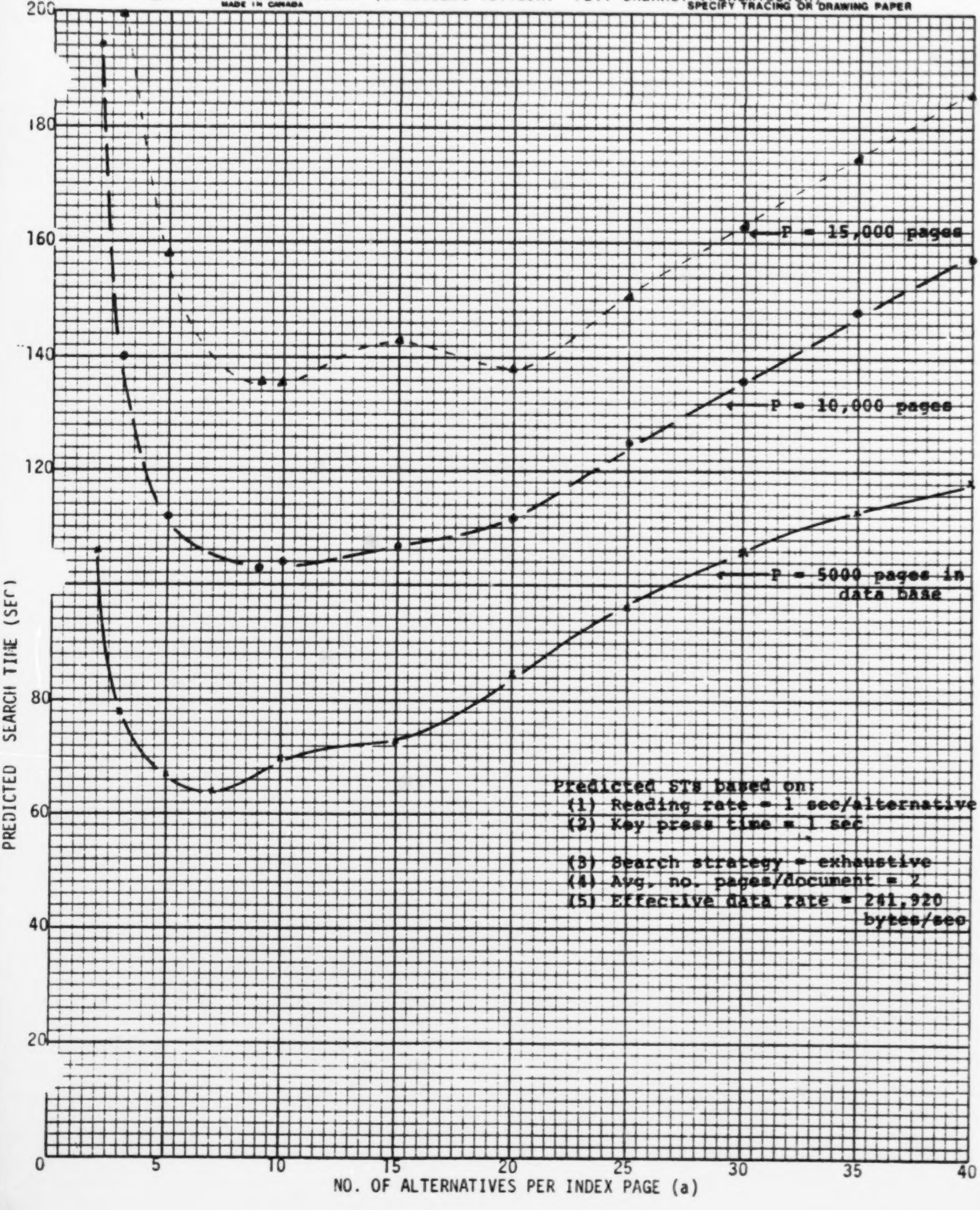


FIGURE 5b: Search Time As a Function of the Number of Alternatives Per Page
(Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA
GA-5 SQUARE 10 X 10 TO THE INCH
DRAWING PAPER

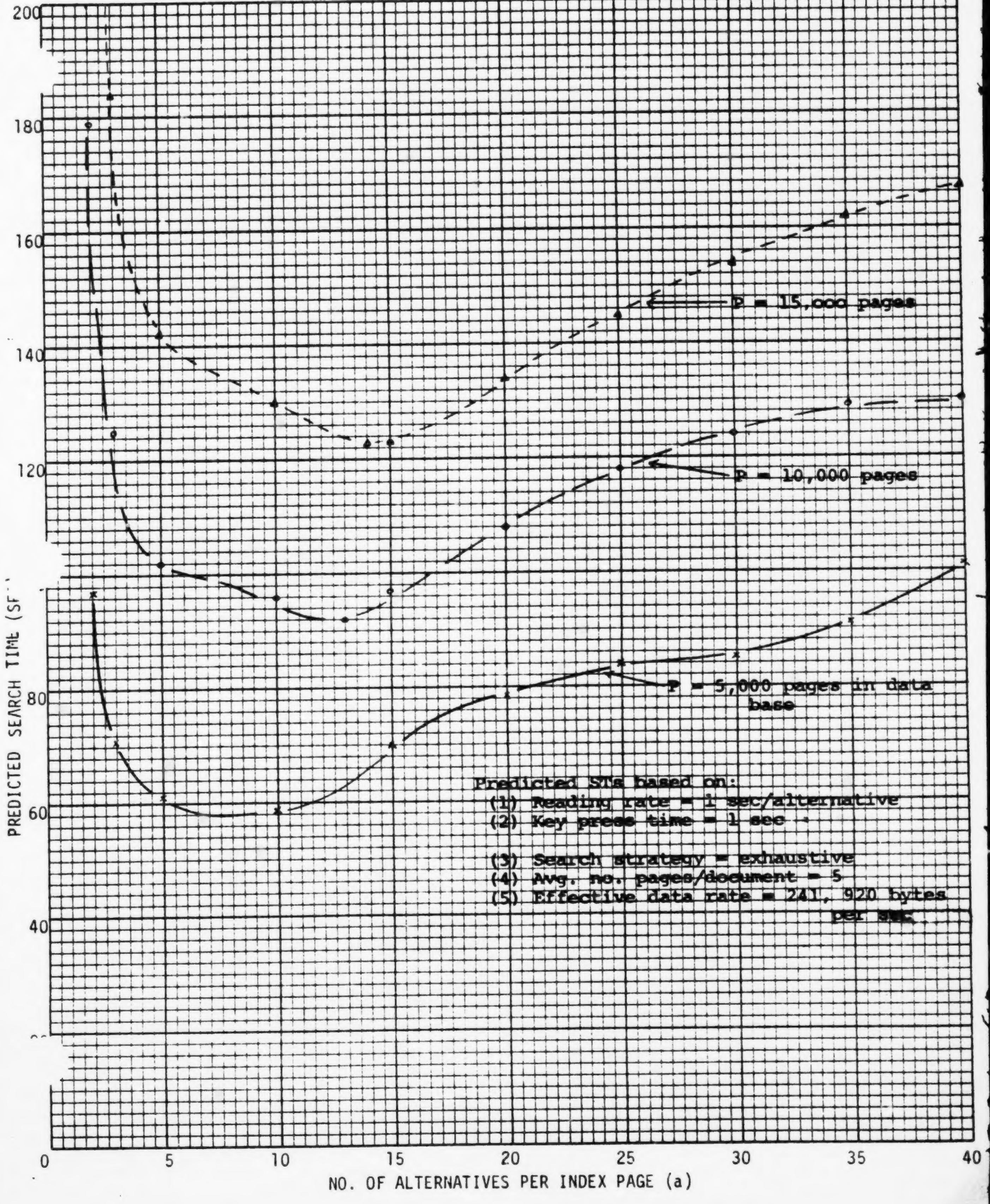


FIGURE 5c: Search Time As a Function of the Number of Alternatives Per Page (Broadcast Telidon: Full-Channel System)

GRAPHIC CONTROLS CANADA LTD. MADE IN CANADA
GC-5 SQUARE 10 X 10 TO THE INCH DRAWING PAPER

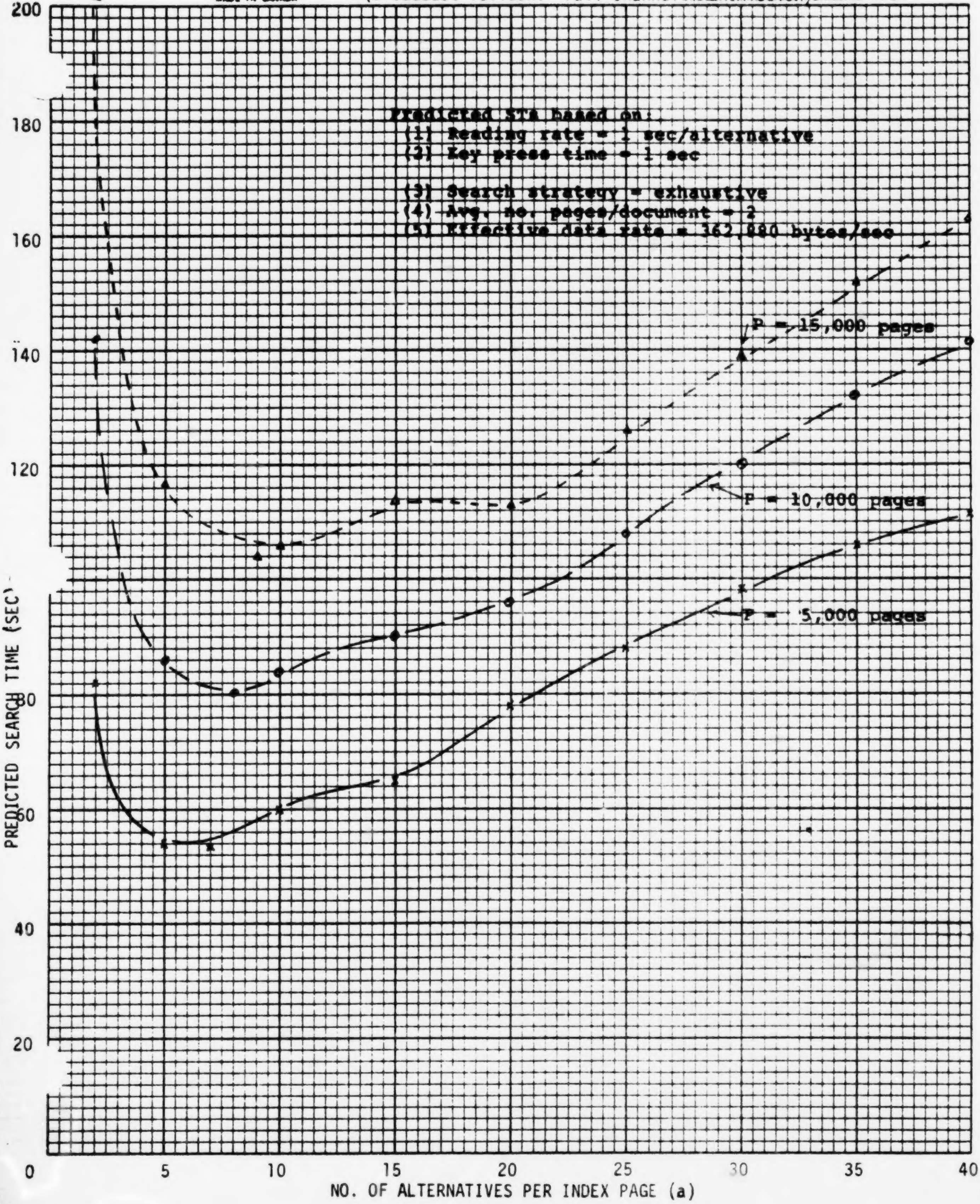


FIGURE 5d Search Time As a Function of the Number of Alternatives Per Page (Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD
MADE IN CANADA
GA-6 SQUARE 10 X 10 TO THE INCH
OR DRAWING PAPER

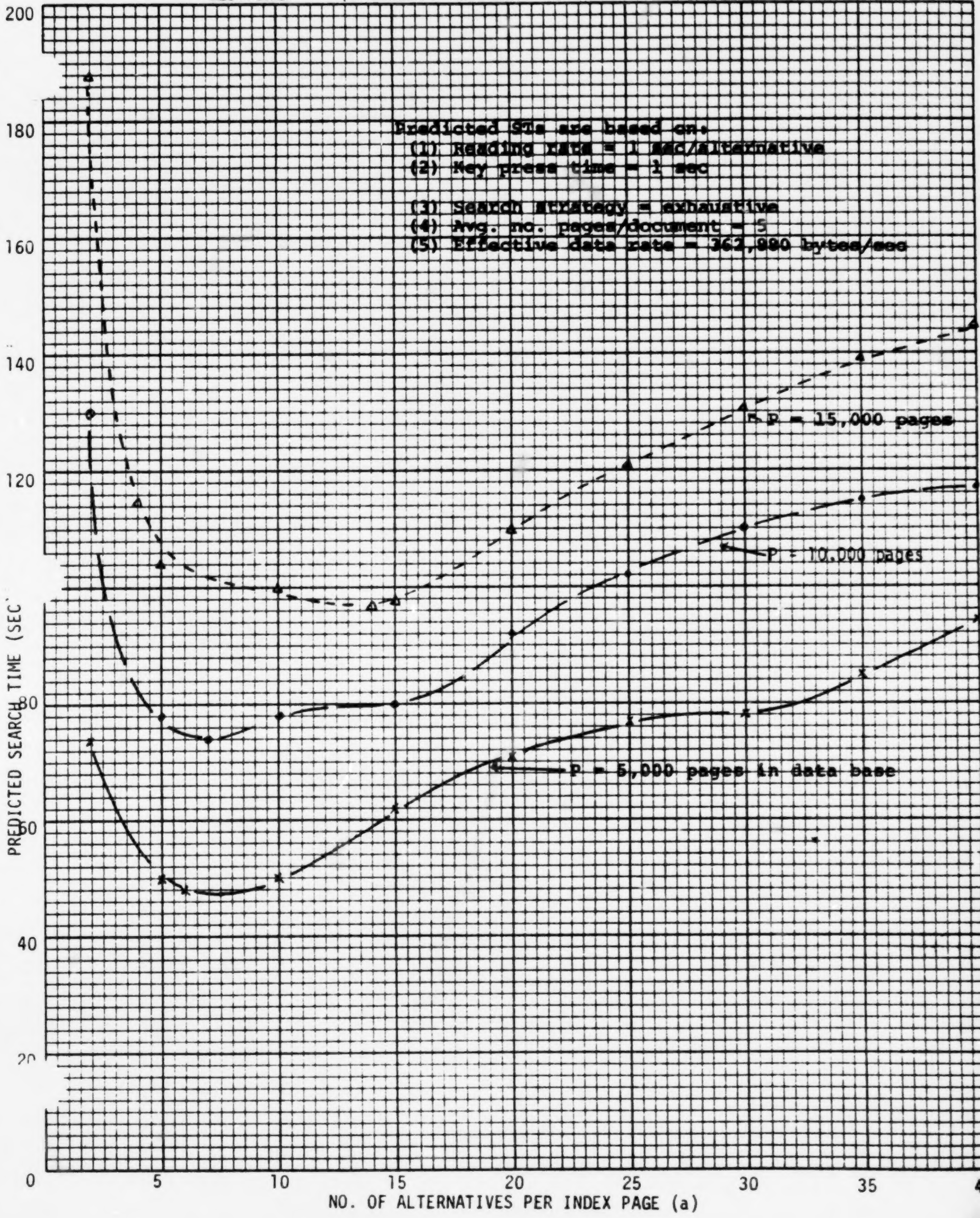


FIGURE:5e Search Time As a Function of the Number of Alternatives Per Page (Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA
10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

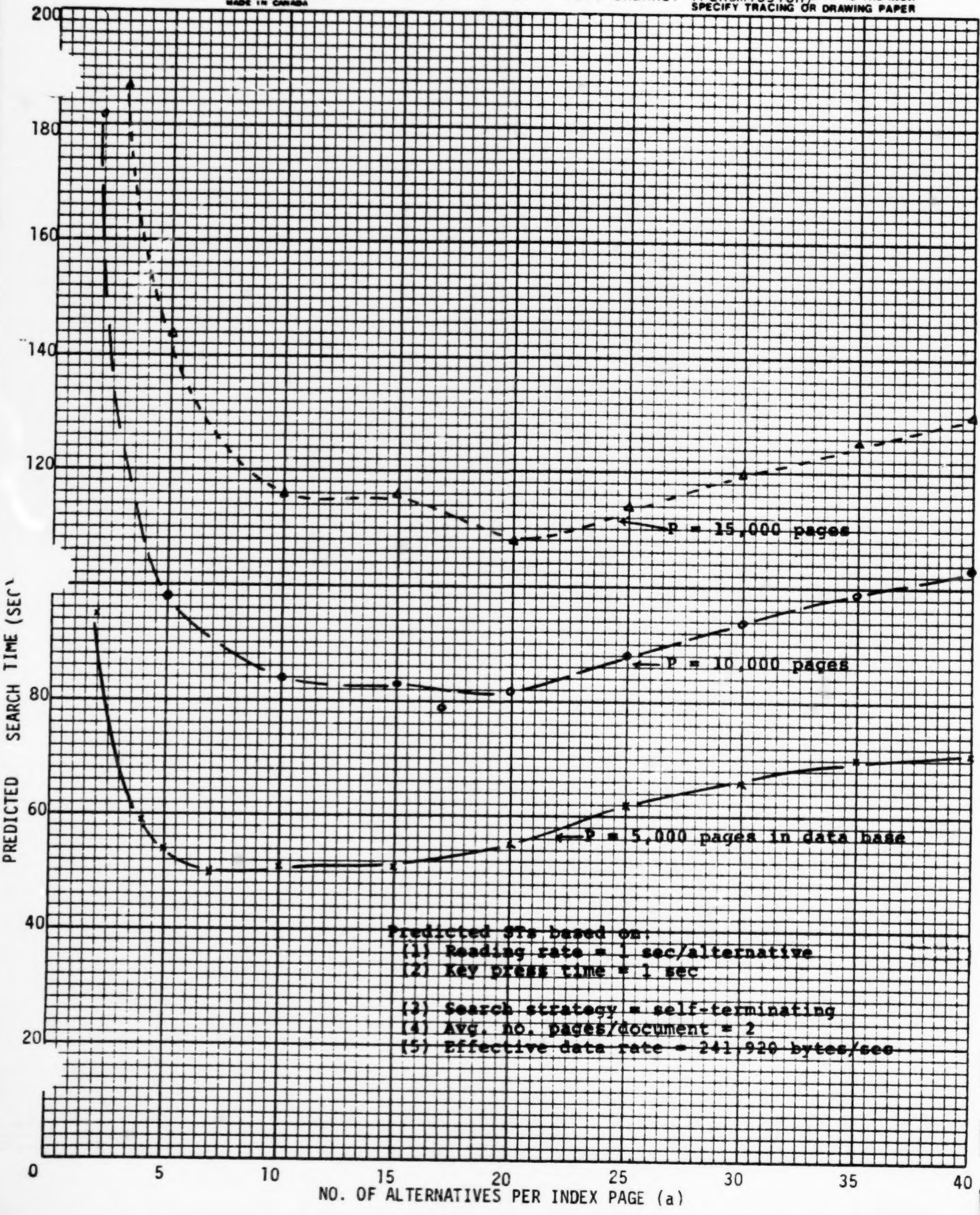
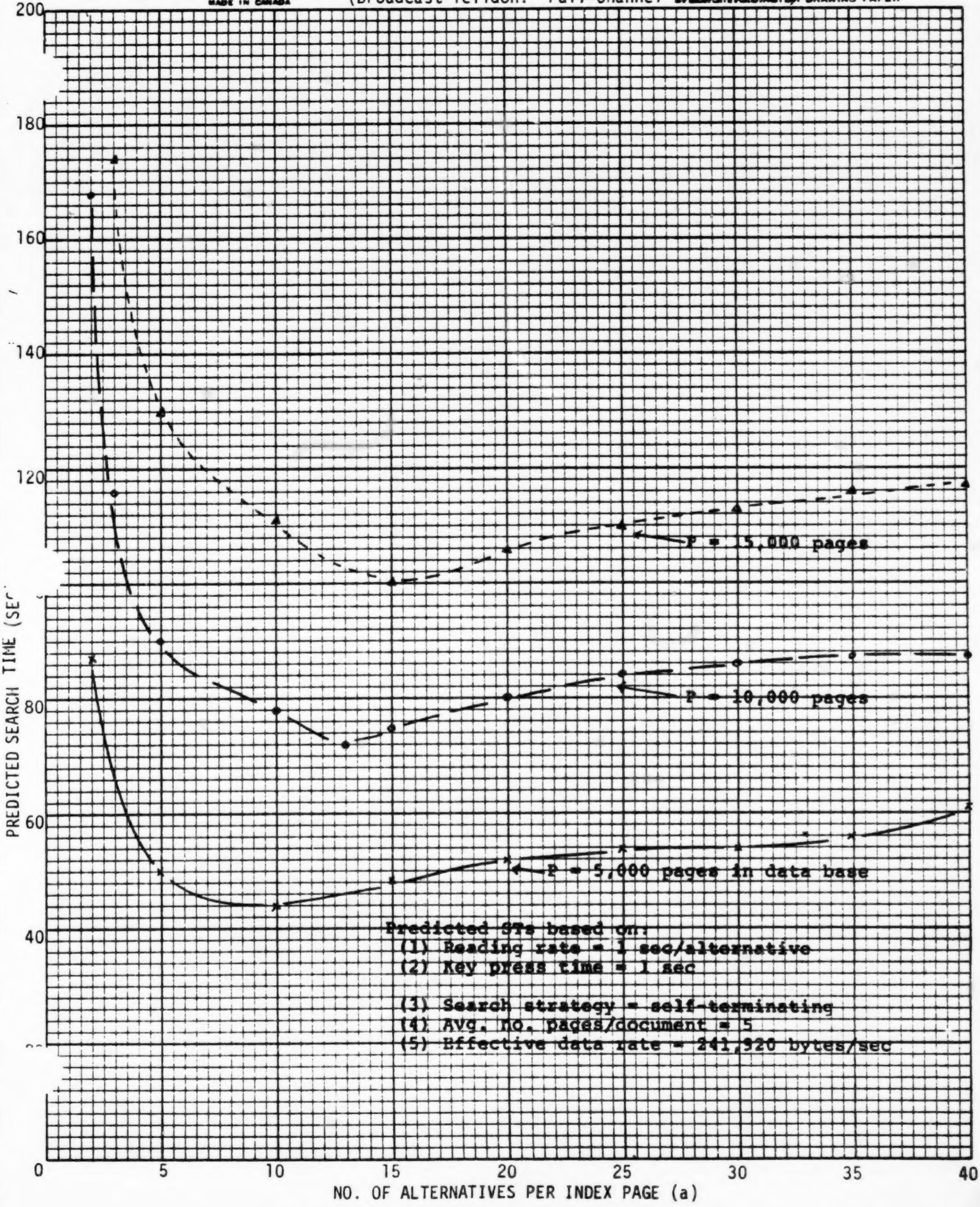


FIGURE 5f: Search Time As a Function of the Number of Alternatives per Page
(Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA
SQUARE 10 X 10 TO THE INCH
DRAWING PAPER



Predicted STs based on:
(1) Reading rate = 1 sec/alternative
(2) Key press time = 1 sec
(3) Search strategy = self-terminating
(4) Avg. no. pages/document = 5
(5) Effective data rate = 241,920 bytes/sec

FIGURE 5g: Search Time As a Function of the Number of Alternatives Per Page (Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA
SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

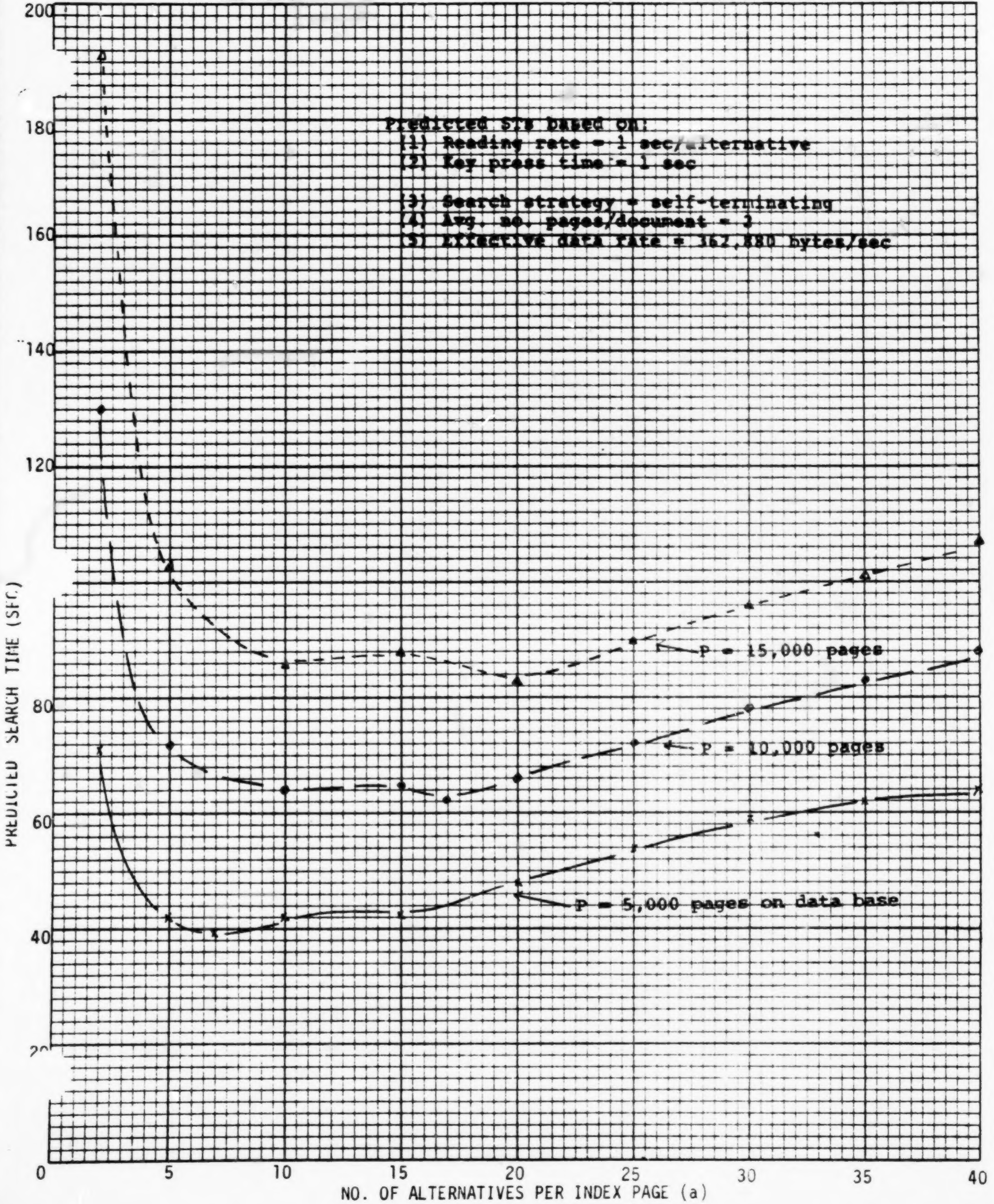


FIGURE 5h: Search Time As a Function of the Number of Alternatives Per Page (Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
MADE IN CANADA
10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

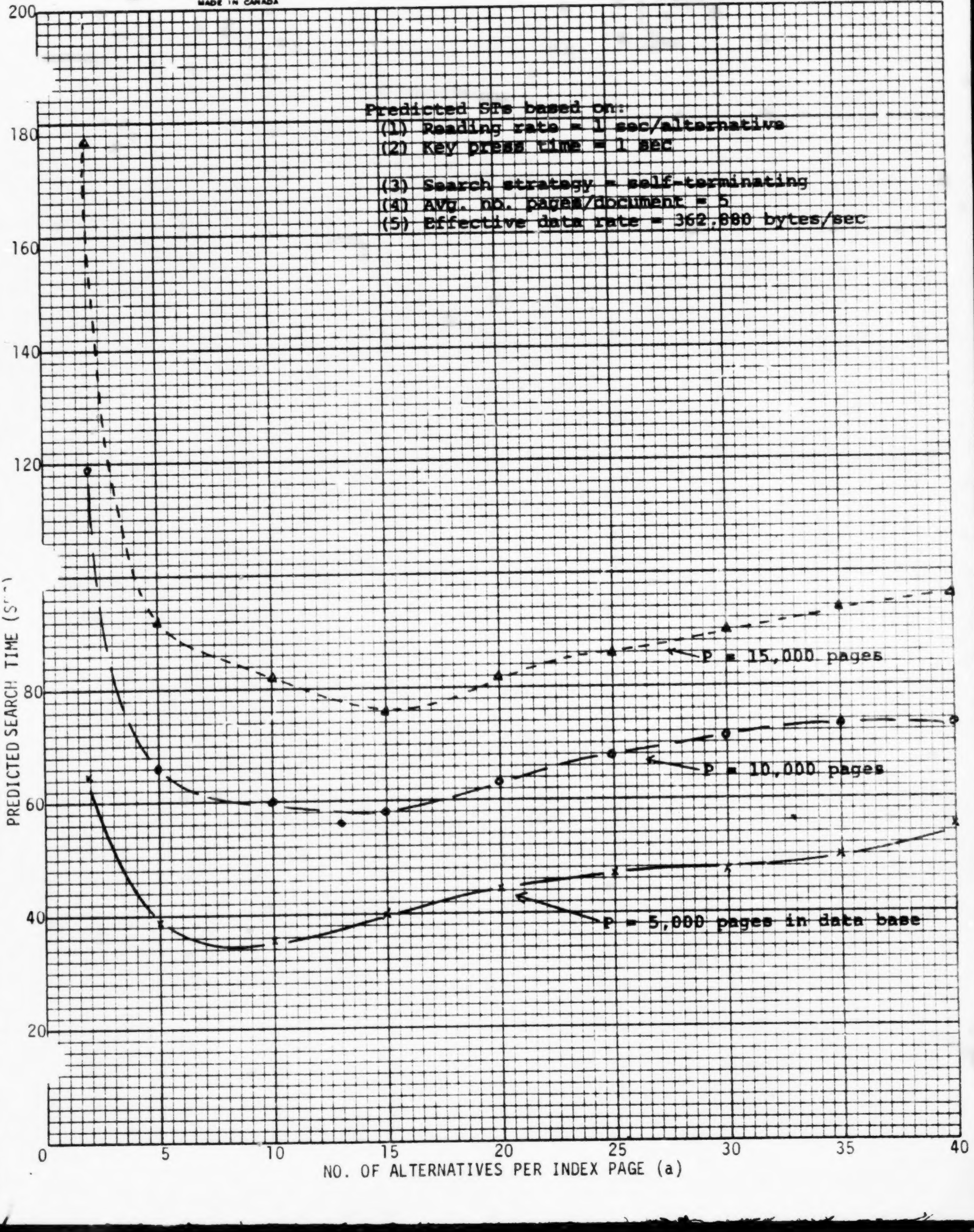


FIGURE 6 : Search Time As a Function of the Number of Alternatives Per Page

(Broadcast Condition: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD
QA-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

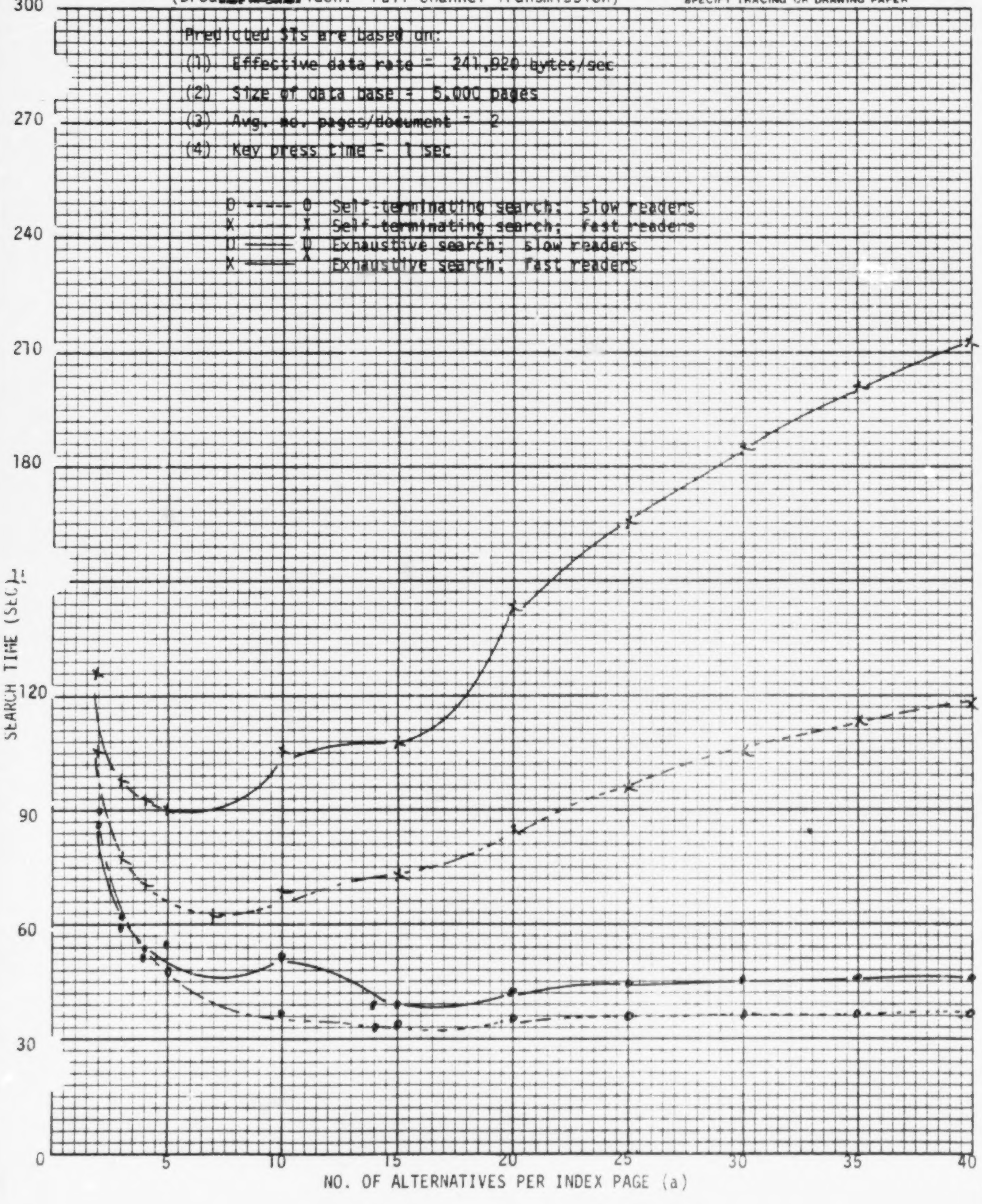
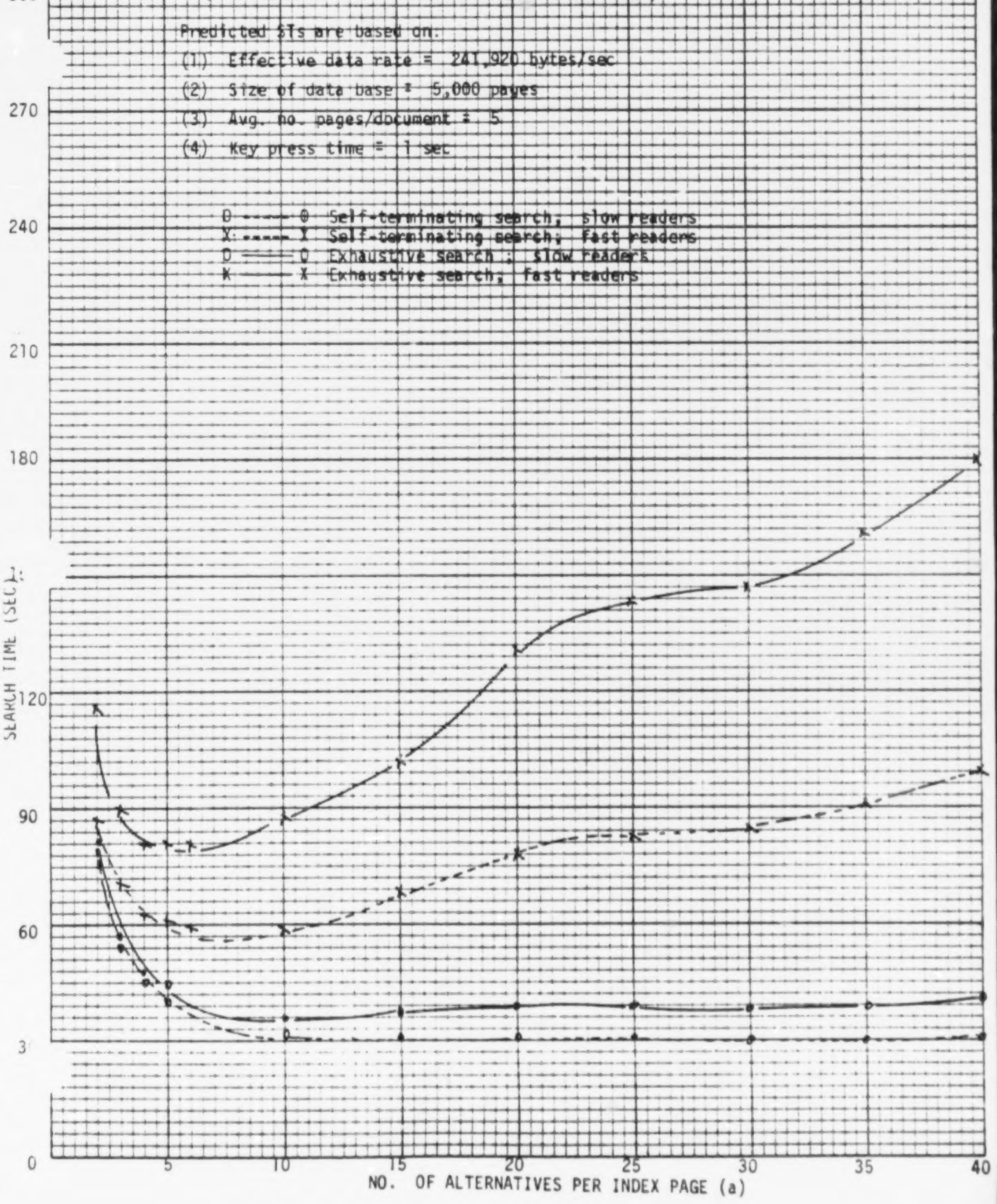


FIGURE 7 : Search Time As a Function of the Number of Alternatives Per Page

(Broadcast Telidon: Full Channel Transmission)

GRAPHIC CONTROLS CANADA LTD
MADE IN CANADA
SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER



Predicted STs are based on:

(1) Effective data rate = 241,920 bytes/sec

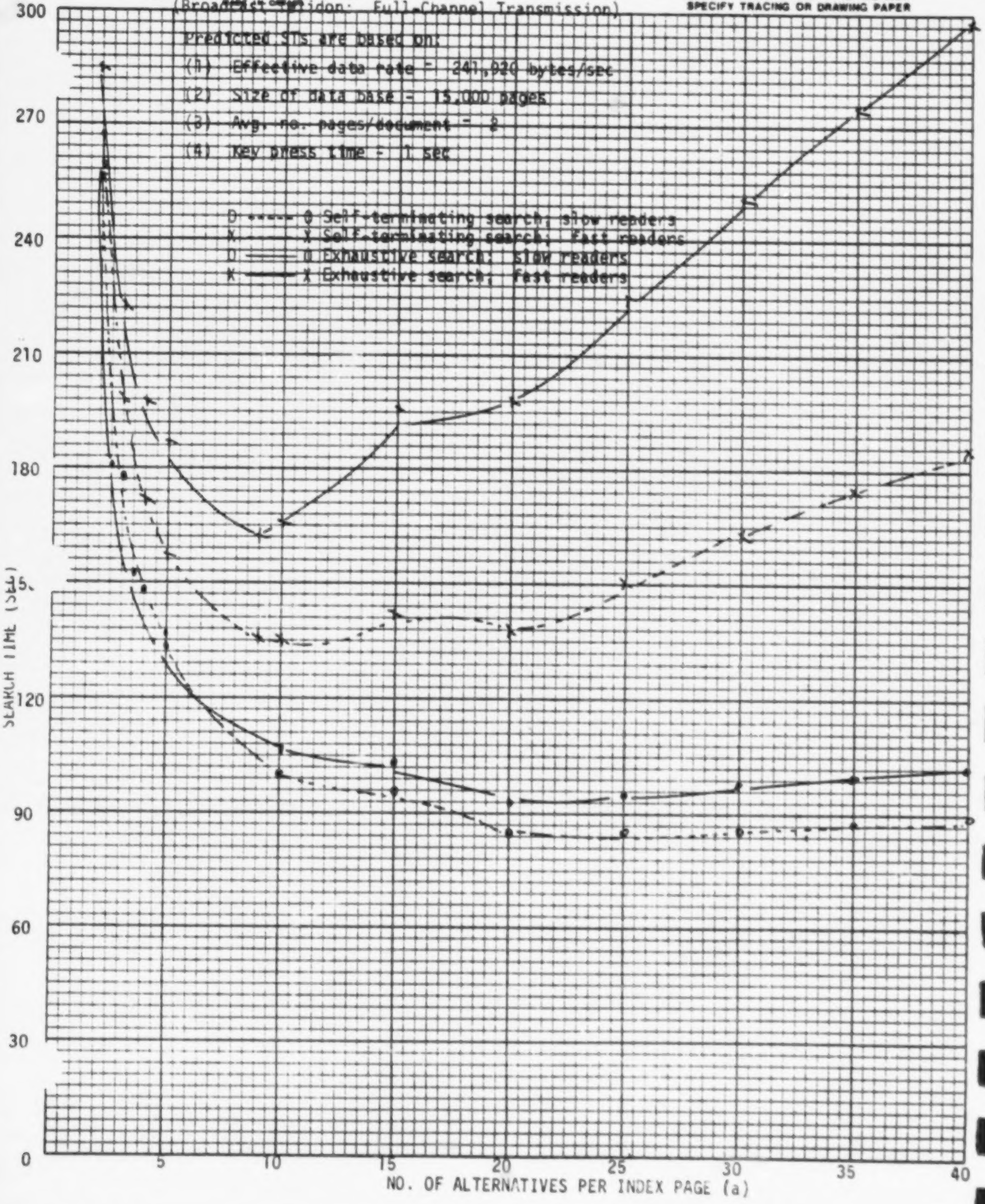
(2) Size of data base = 5,000 pages

(3) Avg. no. pages/document = 5

(4) Key press time = 1 sec

FIGURE 8: Search Time As a Function of the Number of Alternatives Per Page
(Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD
GA-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER



Predicted STs are based on:
(1) Effective data rate = 241,920 bytes/sec
(2) Size of data base = 15,000 pages
(3) Avg. no. pages/document = 8
(4) Key press time = 1 sec

FIGURE 9 : Search Time As a Function of the Number of Alternatives Per Page (Broadcast Simulation: Full-Channel Transmission)

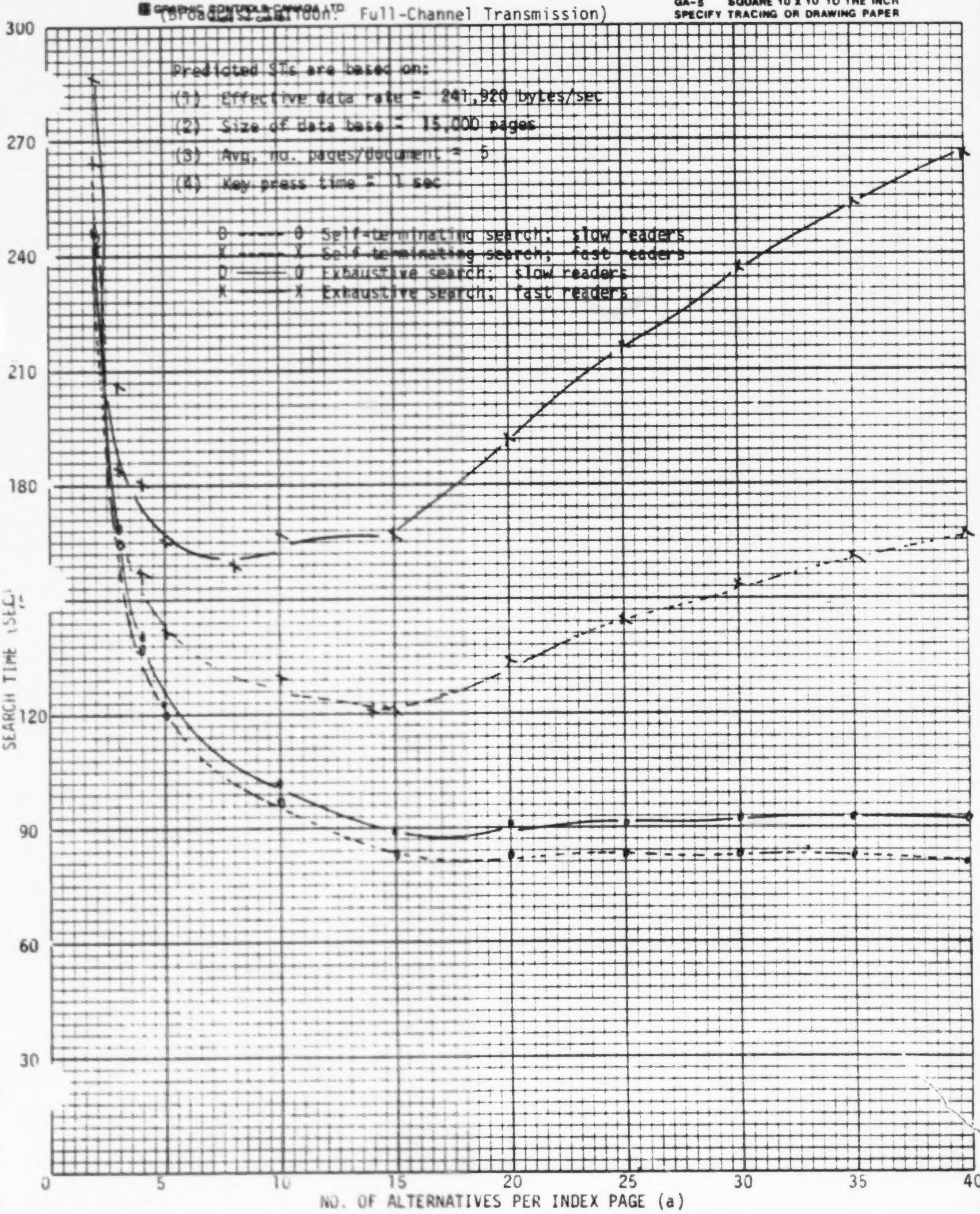


FIGURE 10: Search Time As a Function of the Number of Alternatives Per Page (Broadcast Station: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD MADE IN CANADA
GA-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

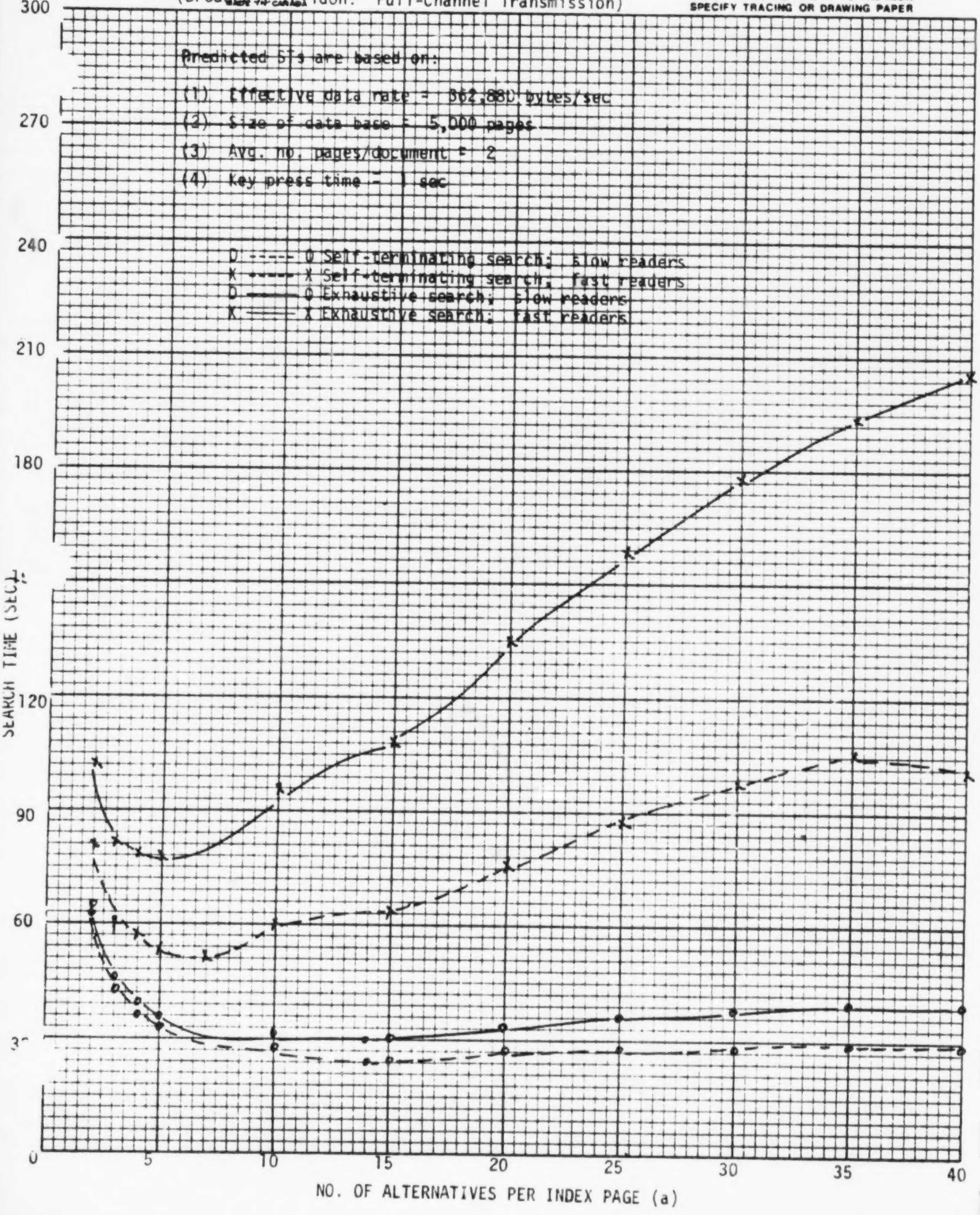


FIGURE 11: Search Time As a Function of the Number of Alternatives Per Page

(Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD
GA-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

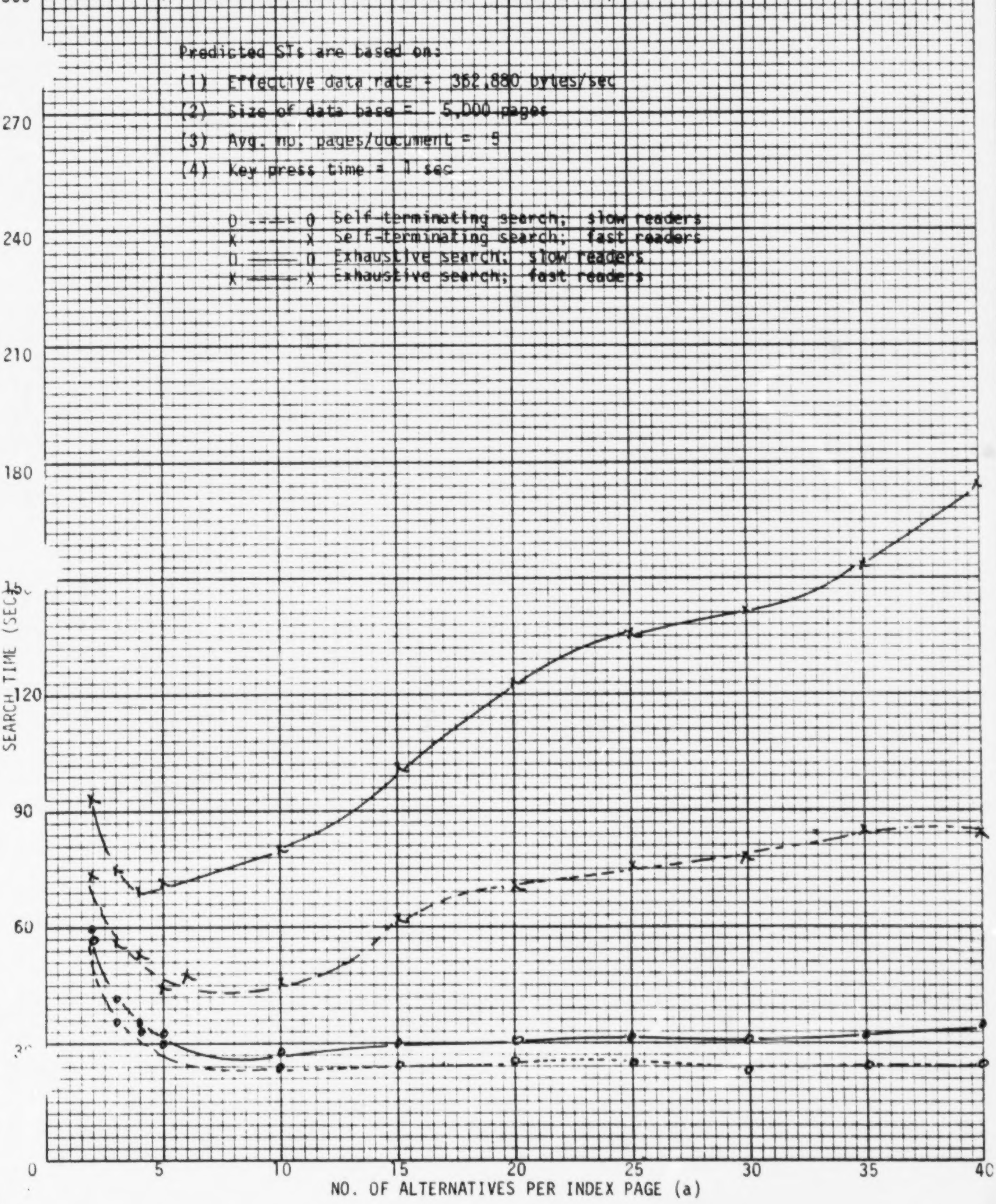
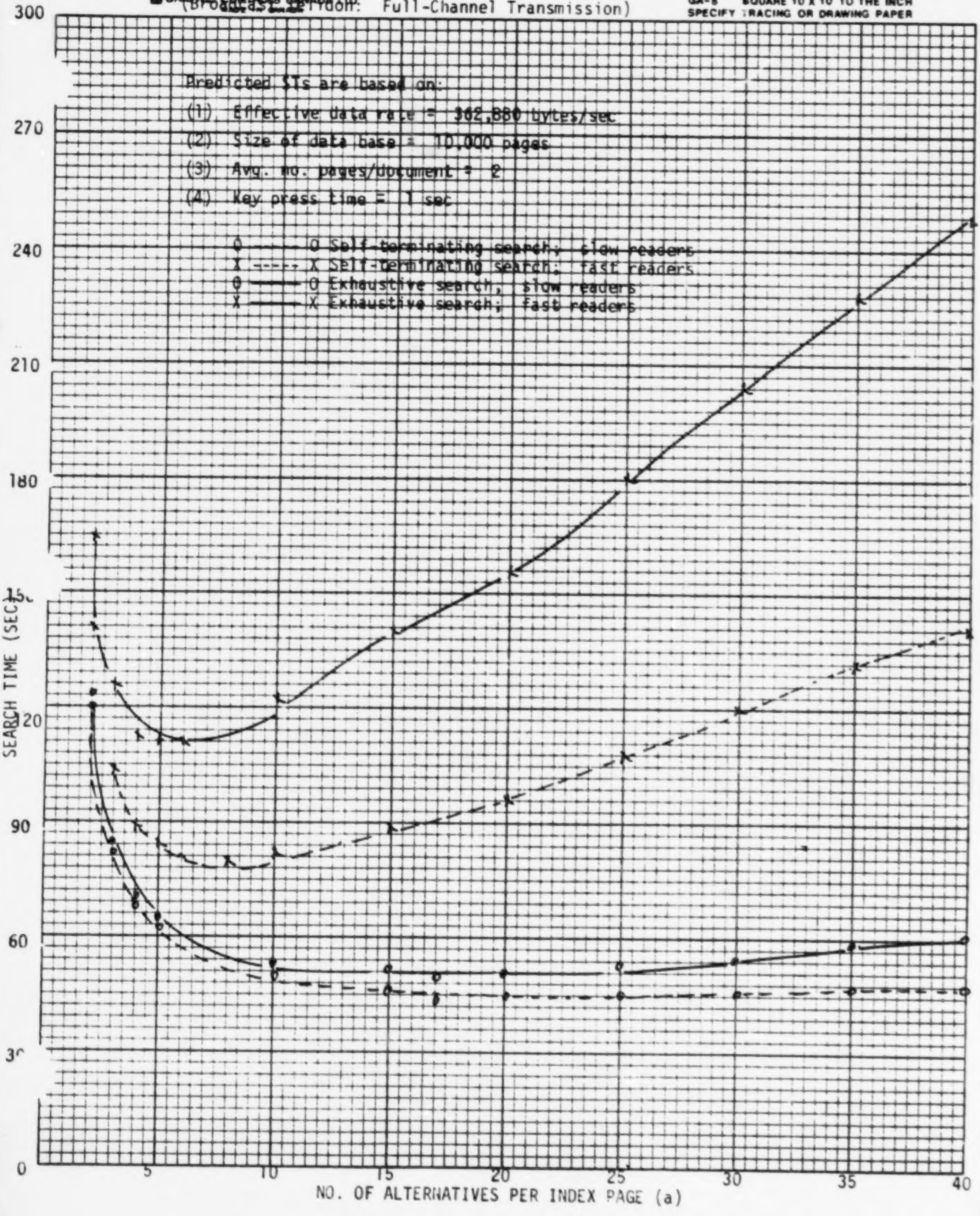


FIGURE 12: Search Time As a Function of the Number of Alternatives Per Page (Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
GA-6 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER



Predicted STs are based on:

(1) Effective data rate = 362,880 bytes/sec

(2) Size of data base = 10,000 pages

(3) Avg. no. pages/document = 2

(4) Key press time = 1 sec

FIGURE 13 : Search Time As a Function of the Number of Alternatives Per Page (Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
GA-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

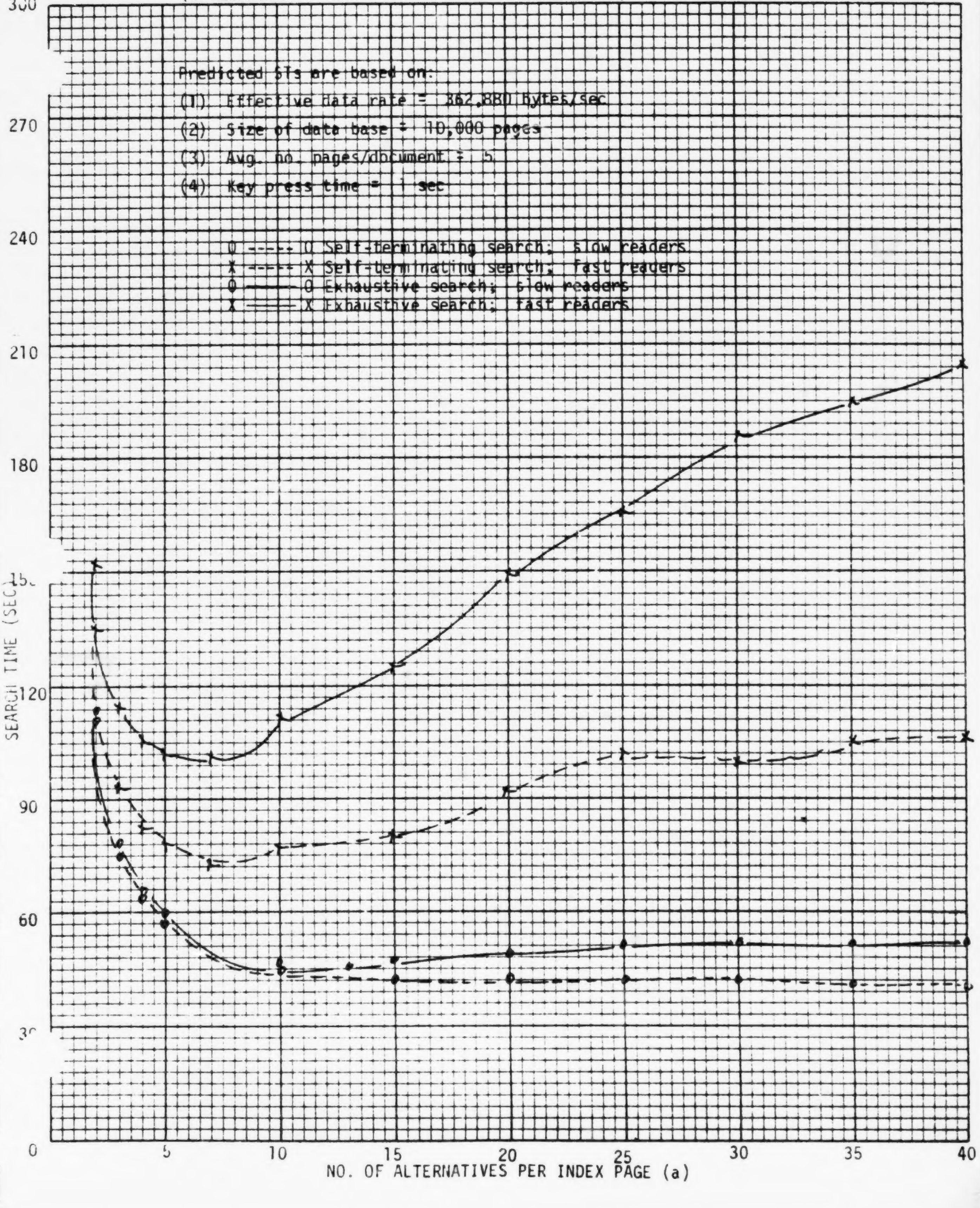


FIGURE14: Search Time As a Function of the Number of Alternatives Per Page (Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
GX-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

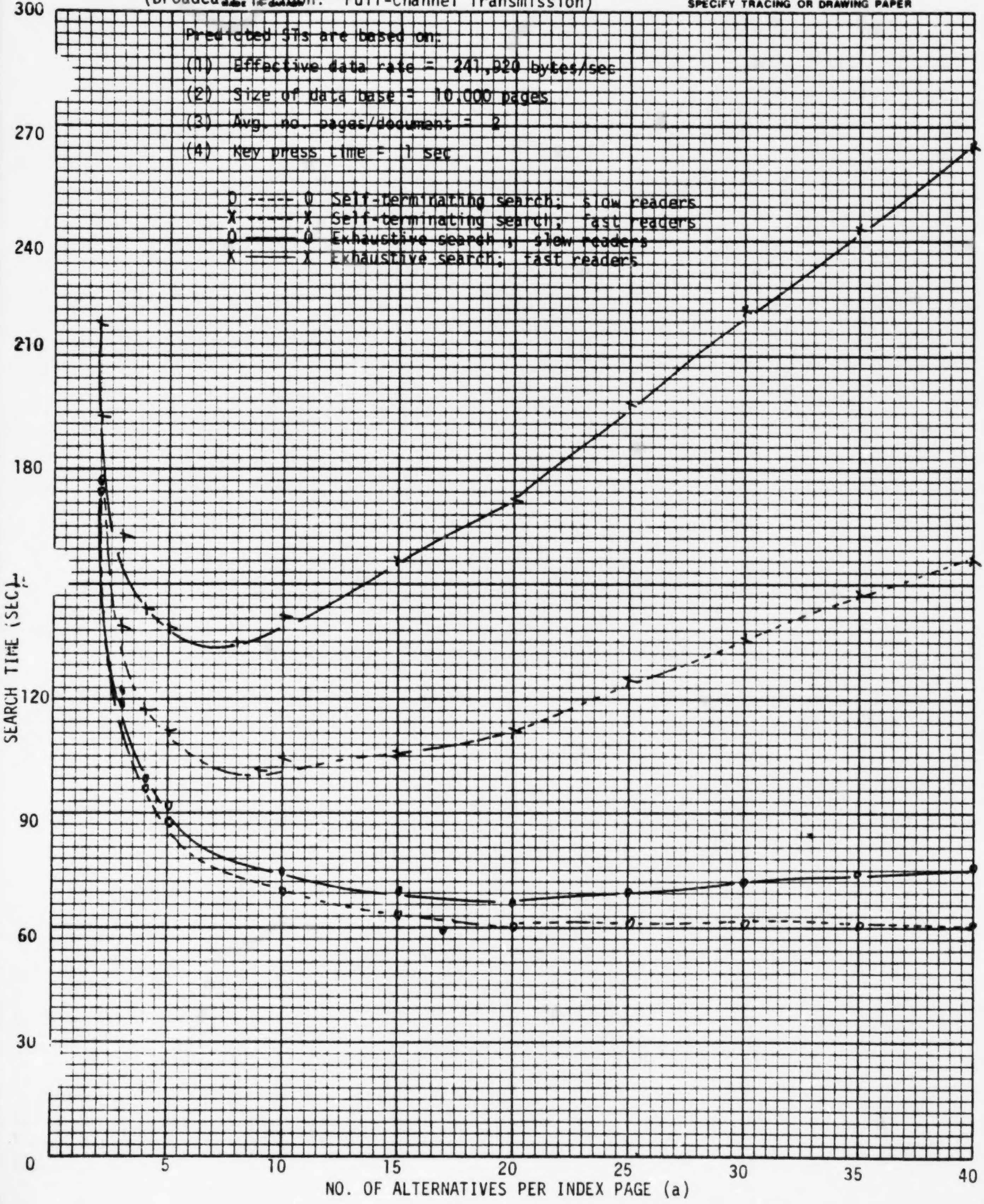


FIGURE 15: Search Time As a Function of the Number of Alternatives Per Page (Broadcast Telidon: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
GA-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

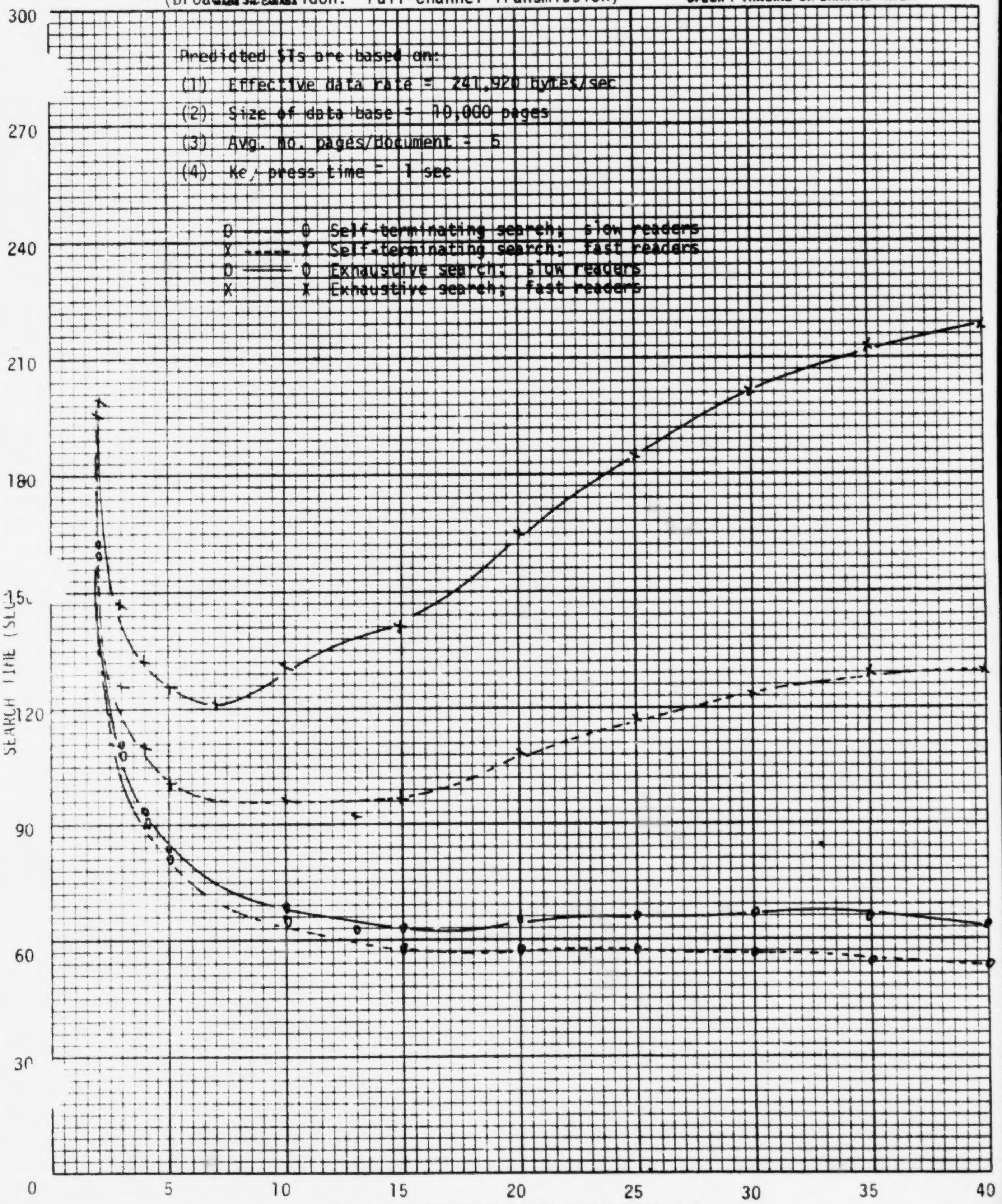


FIGURE 16: Search Time As a Function of the Number of Alternatives Per Page (Broadcast Situation: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER

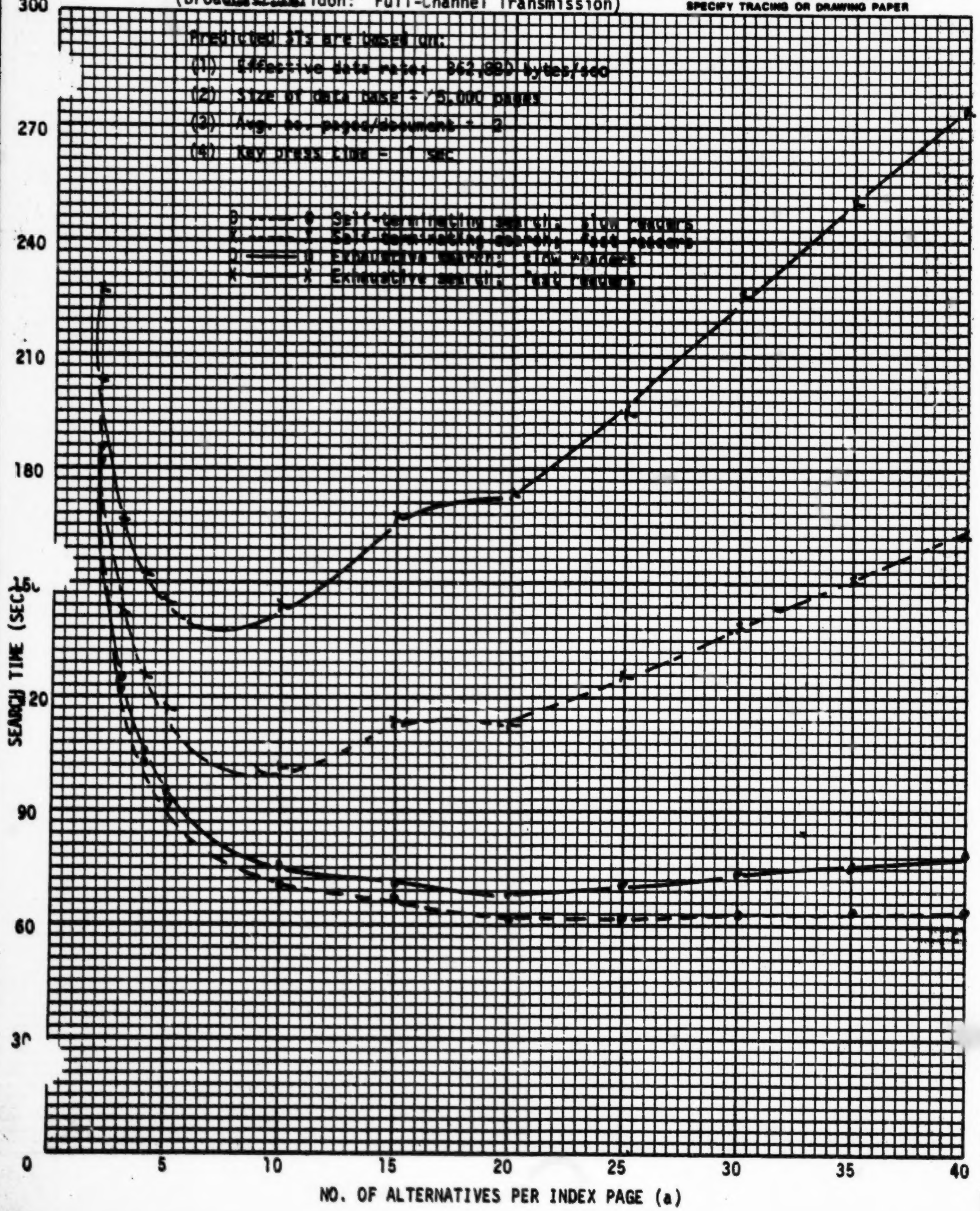
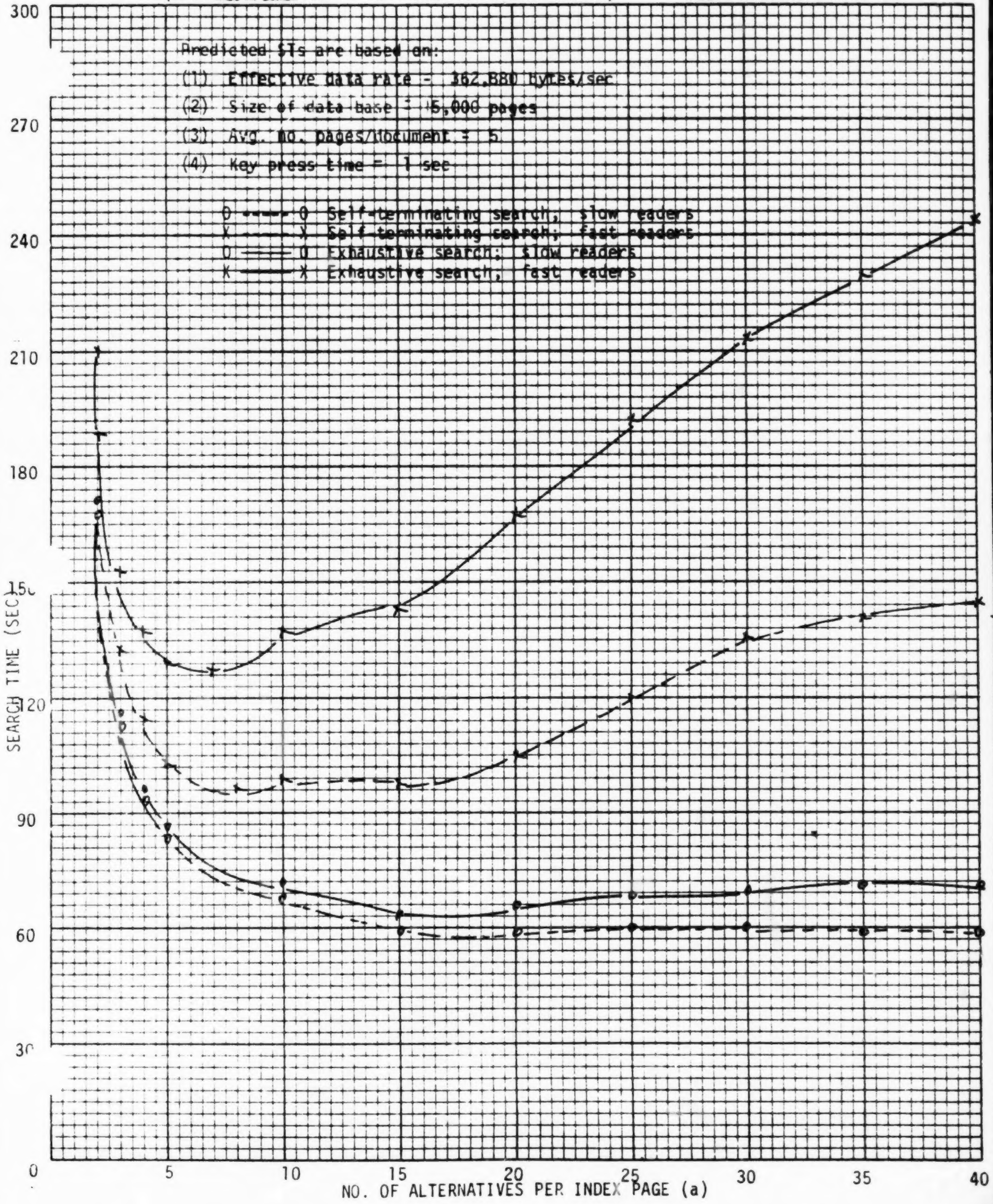


FIGURE 17 : Search Time As a Function of the Number of Alternatives Per Page (Broadcast Mode: Full-Channel Transmission)

GRAPHIC CONTROLS CANADA LTD.
GA-5 SQUARE 10 X 10 TO THE INCH
SPECIFY TRACING OR DRAWING PAPER



Government of Canada Gouvernement du Canada

MEMORANDUM NOTE DE SERVICE

TO / A: Eric Lee

FROM / DE: Bob FitzGerald

SECURITY - CLASSIFICATION - DE SÉCURITÉ:

OUR FILE - N/RÉFÉRENCE:

YOUR FILE - V/RÉFÉRENCE:

DATE: September 17, 1979

SUBJECT / OBJET: BROADCAST TELIDON WAITING TIMES (FULL-CHANNEL TRANSMISSION)

As discussed this morning on the telephone, here are some calculations of the average waiting time for reception of a broadcast Telidon page. Note that the waiting time is the sum of the interval between the user's request and the receipt of the first line of the page, and the actual transmission time for that page.

Assumptions

- Full-channel transmission (N_L = 252 usable TV lines)
- No. of data-bytes per TV line (B_L) = 16, 20, or 24
- Avg. no. of bytes per Telidon page (B_P) $\simeq$ 600
- No. of pages in broadcast cycle (N_P) > 80, to ensure that any two lines from one specific page are separated by at least 5 msec.

Effective data rate (f_D) = BL X NL X 60

e.g. BL = 24

$$f_D = 24\ \frac{\text{bytes}}{\text{line}} \times 252\ \frac{\text{lines}}{\text{field}} \times 60\ \frac{\text{fields}}{\text{second}} = 362880\ \frac{\text{bytes}}{\text{second}}$$

$$\text{CYCLE TIME } (t_c) = \frac{600 \times N_P}{f_D}$$

$$\text{e.g. } N_P = 10000,\ t_c = \frac{600 \times 10000}{362880} = 16.5 \text{ sec.}$$

or, alternatively,

$$N_P = \frac{t_c \times f_D}{600}$$

$$\text{e.g. } t_c = 20 \text{ sec., } N_P = \frac{20 \times 362880}{600} = 12096 \text{ pages (average)}$$

The first component of the waiting time t_1 is $0 \leq t_1 \leq t_c$

Average value of $t_1 = \frac{t_c}{2}$

.../2

Thus if $t_c = 20$ sec, $\underline{t_1 = 10 \text{ sec.}}$

The second component of the waiting time t_2 is the time required to transmit the desired (average) page.

The number of TV-lines required to transmit the average 600-byte page is

$$Lp = \frac{600}{BL}$$

$$\text{e.g.} \quad BL = 24,\ LP = \frac{600}{24} = 25 \text{ lines}$$

If we assume that lines of information are interleaved such that 1 out every 100 TV lines contains data from the desired page, the total number of TV lines in the interval required for transmission of one complete page is 25 X 100 = 2500, and the transmission time will be

$$t_2 = \frac{2500 \text{ lines}}{252 \text{ lines/field} \times 60 \text{ Field/sec}} = .165 \text{ sec.}$$

Thus the total waiting time, using the assumptions listed above, will be

$$t = t_1 + t_2 = 10.165 \text{ sec.}$$

It should be mentioned that the considerable difference between t_1 and t_2 is particularly marked in the full-channel case. If vertical-blanking-interval (VBI) transmission is assumed, the results are quite different.

I hope this analysis is of some assistance to you. Since you were anxious to have this as soon as possible, I was unable to discuss these calculations with John Storey, and therefore cannot guarantee that there are no errors in my approach, or that this analysis reflects John's most recent ideas on this subject. If possible, I would suggest that you discuss this with him upon his return next monday, before publishing your paper.

Bob FitzGerald

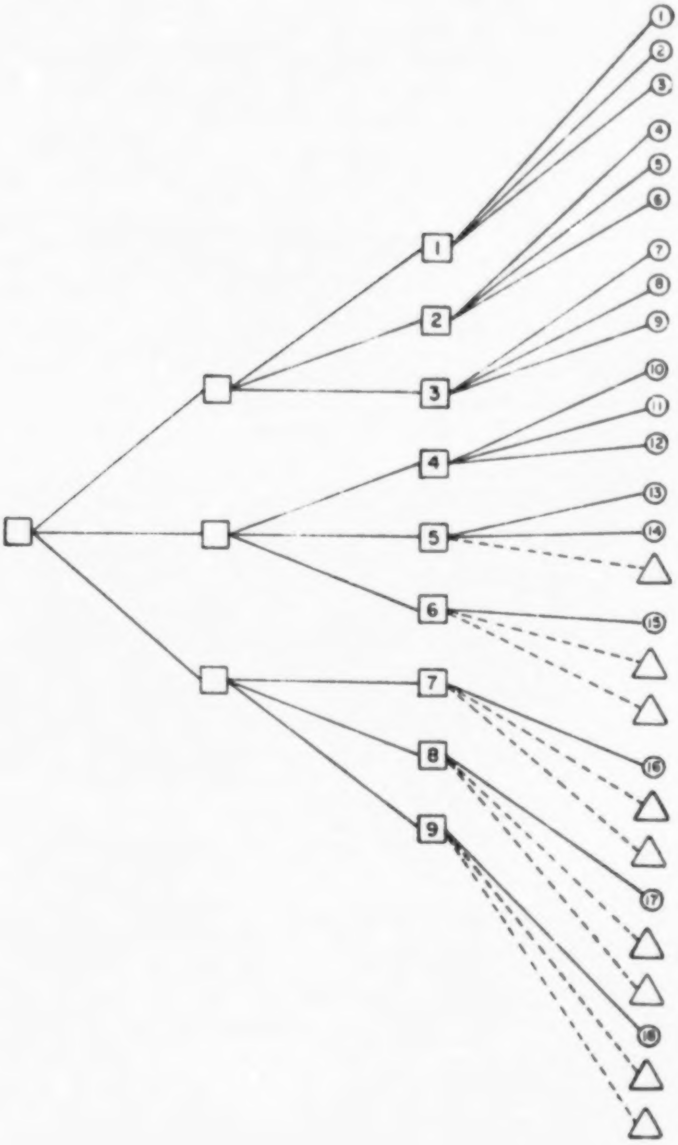
Bob FitzGerald
Image Communications

BFG/cb
cc: J.R. Storey

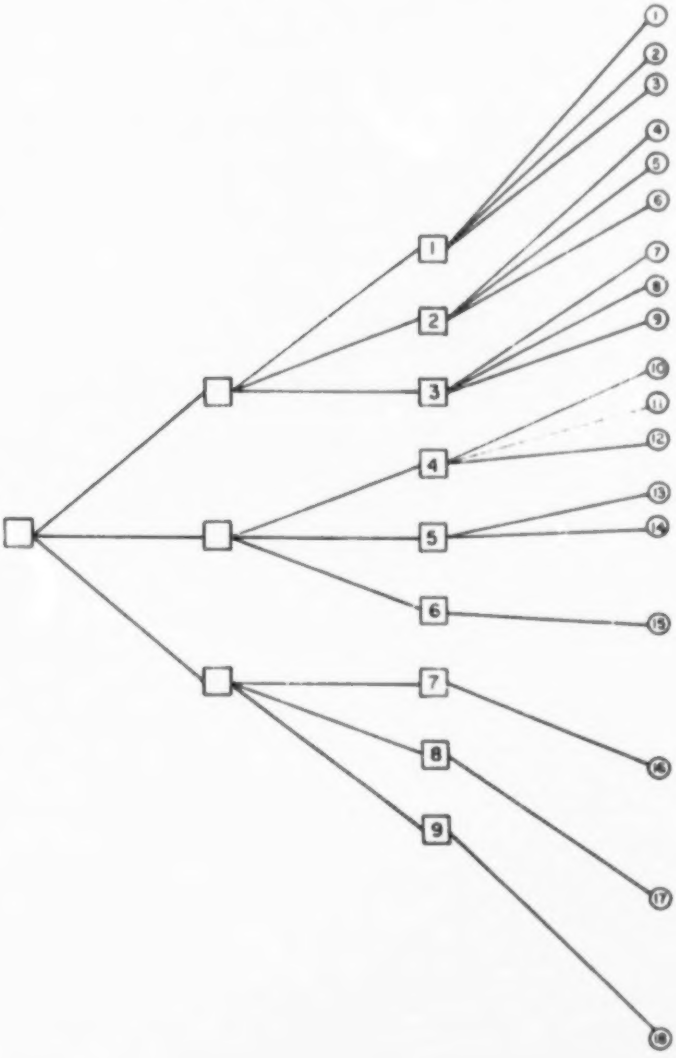
APPENDIX

FURTHER DISCUSSION OF THE DERIVATION OF EQUATION 3

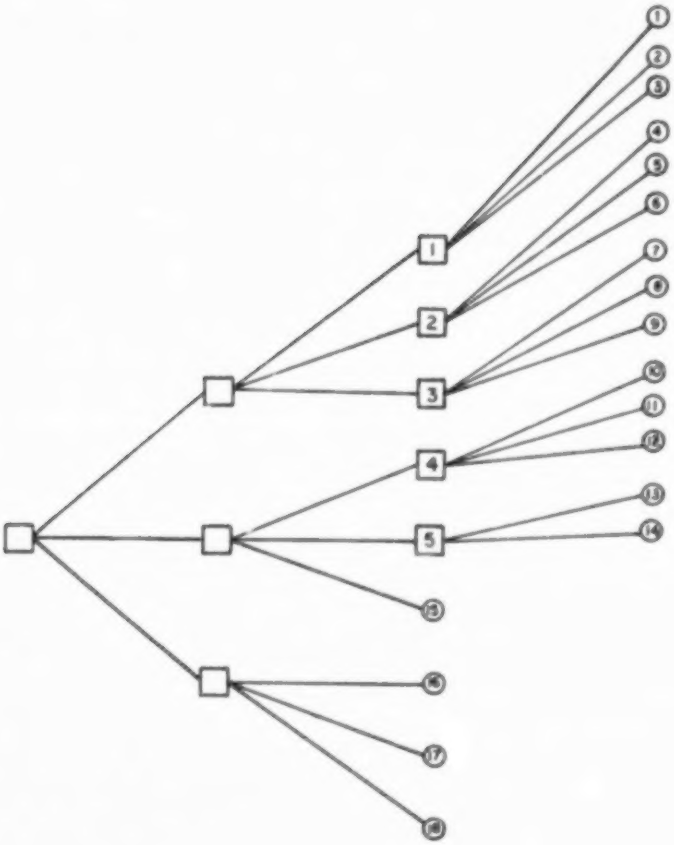
A concrete example is presented below to clarify the derivation and use of Equation 3 (see page 11 and 12). Consider a small data base containing 18 documents. These documents are accessed through an index tree consisting of 3 levels, each index page displaying 3 alternatives. That is, $d = 18$, $p_m = 3$, $a = 3$. This data base is displayed in the figure below.



All index or menu pages are represented by squares, the 18 documents by circles, and the possible paths through the tree by solid lines. The triangles represent documents that could be added to this data base without adding more alternatives/index page or adding more index pages. Dashed lines are used to connect such "potential" documents to the tree. Note that at least one of the 18 documents (circles) has been connected to each of the index pages at level 3 of the tree. Furthermore, index pages 6 through 9 each access one of the 18 documents (circles) and a - 1 = 2 of the imaginary documents (triangles). Since the imaginary documents are never accessed they can be dropped from the tree. The tree that remains after dropping the triangles is presented below.



Note that index pages 6 through 9 access only a single document (circle) each. This means that index pages 6-9 each have only a single alternative. Such index pages are redundant because the documents (circles 15-18) can be accessed directly from level 2 of the tree as shown in the representation of the tree below.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1
2
3
4
5

Note that 4 documents - 15 through 18 - are accessed directly at level 3 of the tree. The average length of path, $\underline{p}$, through the tree is shortest in this last figure. The shorter paths result in shorter search times. This optimum tree can always be found by pairing up each set of $\underline{a} - 1$ triangles with one circle, deleting the triangles, and finally eliminating index pages that retrieve only a single document (circle).

Equation 3 is used to compute $\underline{n}$, the number of documents (circles) that are accessible at level $\underline{p_m}$ (level 3 in our example) of the tree:

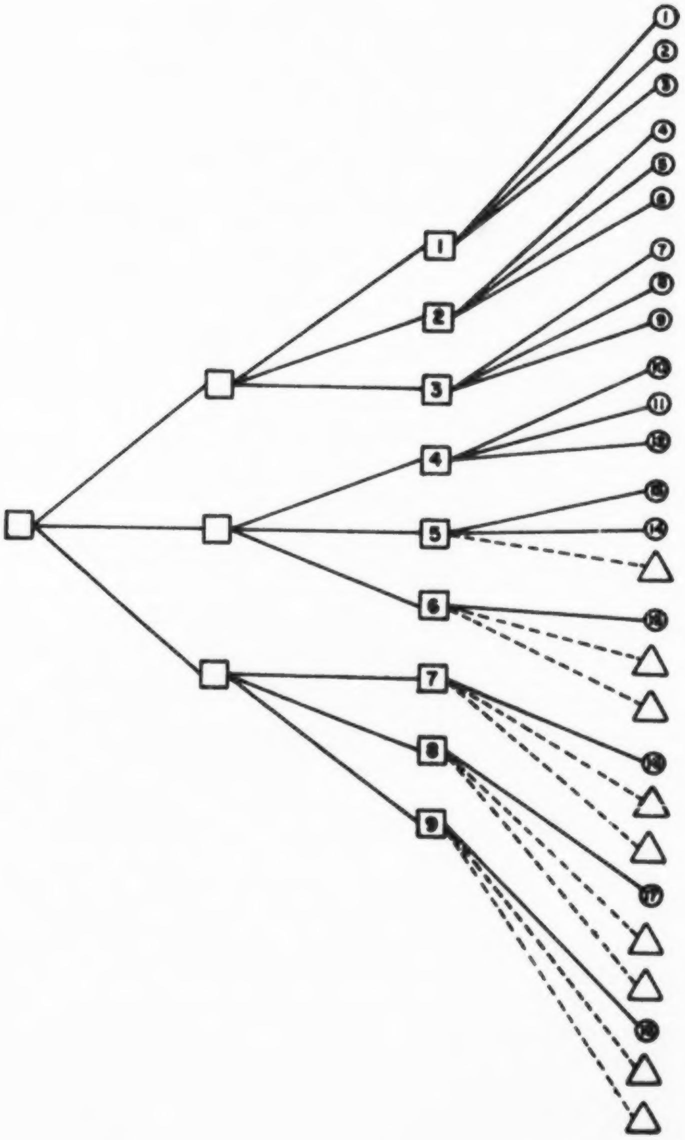
$$n = \frac{a^{p_m} - d}{a - 1}$$

The numerator $(a^{p_m} - d)$ of this equation represents the number of triangles (i.e. possible documents) while the denominator represents the number of triangles that are automatically lost by moving the one circle up one level in the tree. $\underline{n}$ represents the number of sets that can be made each containing one circle and $\underline{a} - 1$ triangles. In our example,

$$n = \frac{2^3 - 18}{3 - 1}$$

$$= 4.5 = \underline{\underline{4}}$$

It can be seen that the number of documents as computed by Equation 3 corresponds to the number actually found at level 3 of the tree in the previous diagram.


1
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9
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⑧
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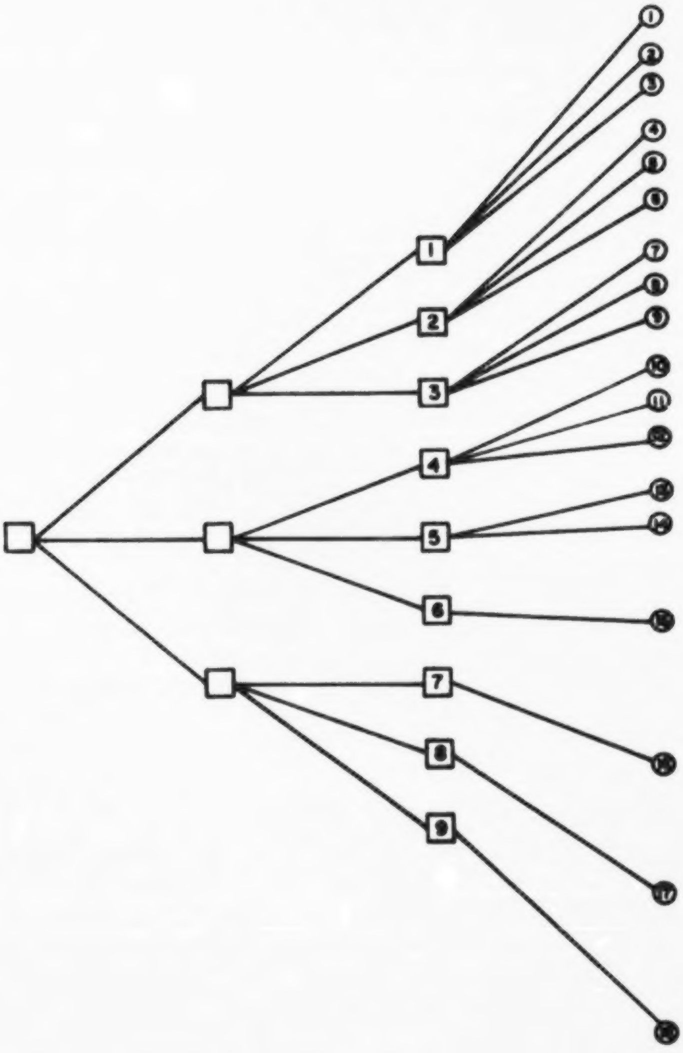
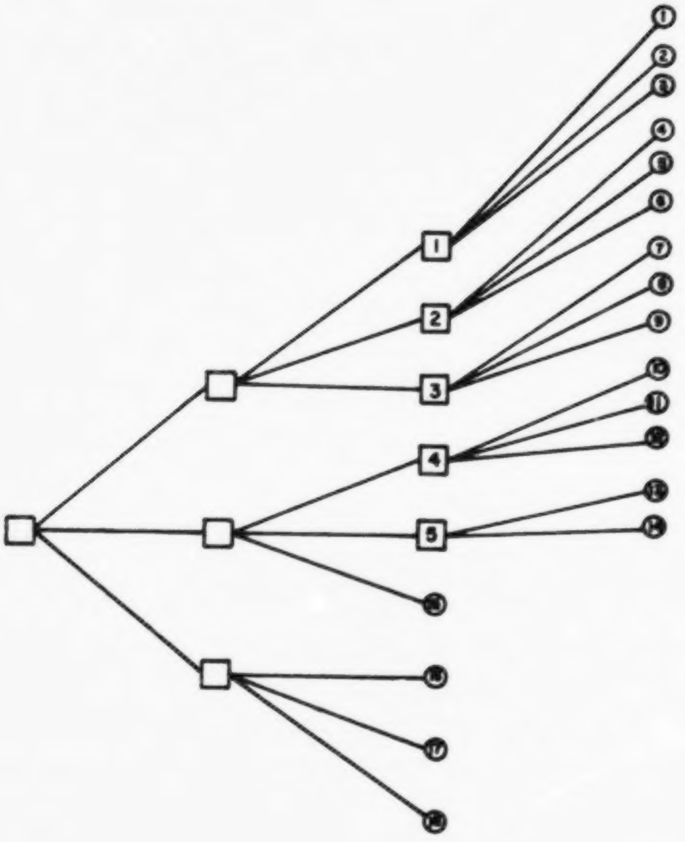
⑱




1
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4
5
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②
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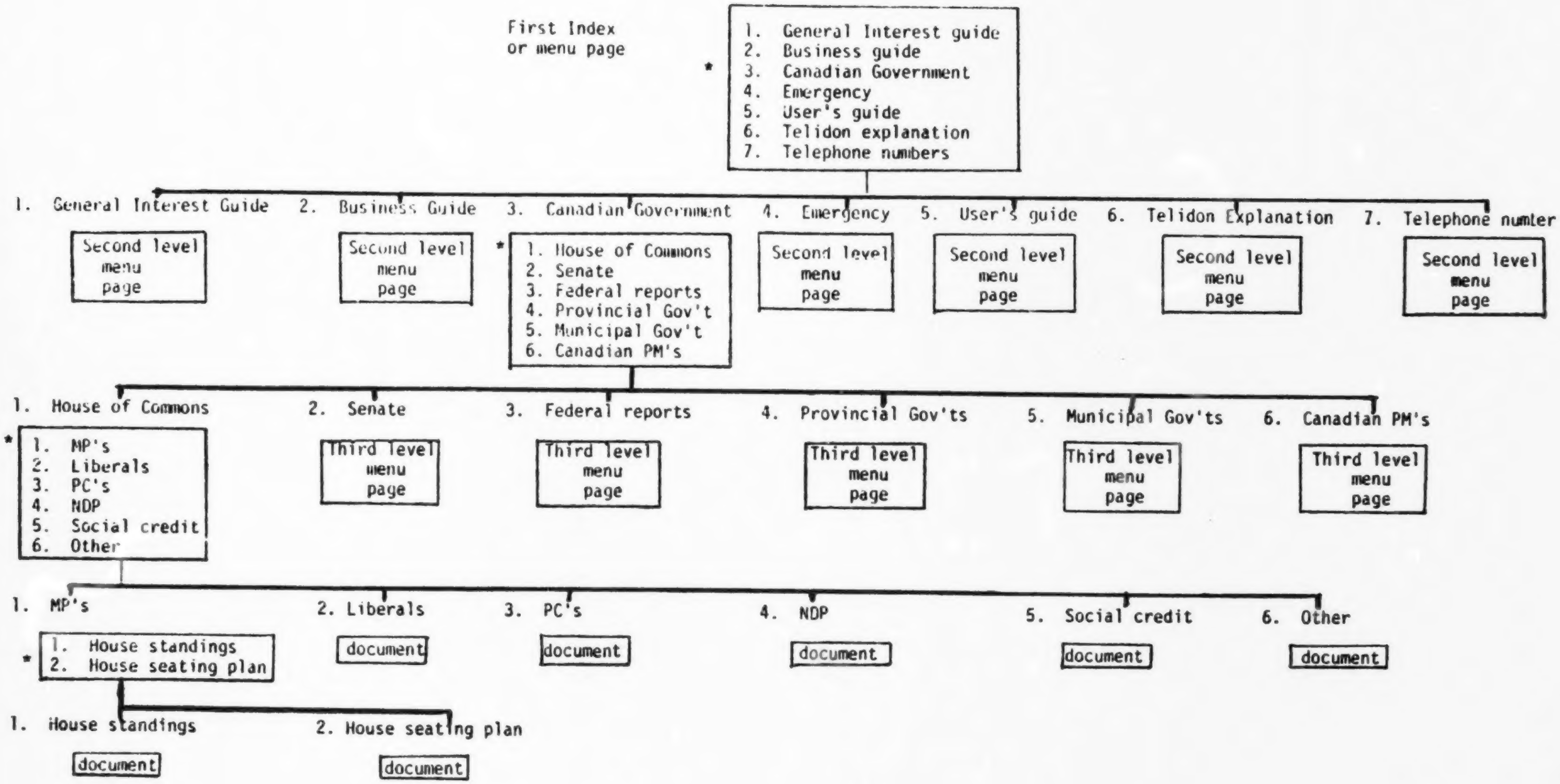
⑰
⑱

EVALUATION OF TREE STRUCTURED ORGANIZATION OF INFORMATION ON TELIDON

by Eric Lee and Susane Latremouille
Department of Communications
Ottawa, Ontario

Telidon is a new Communications technology developed by a team of scientists at the Department of Communications Research Centre in Ottawa. This new technology will permit information retrieval from data bases (information banks) through the home television set in a more flexible and precise way from a technological point of view than existing public information retrieval systems. The implementation of this new system will probably involve extensive retrieval of information by the public which means that the form of communication between computer and user of the system is essential to the success of this system. At present, users retrieve information from Telidon by making selections from menus which are structured in the form of a tree or hierarchy (see Figure 1).

Figure 1: EXAMPLE
ILLUSTRATING PART OF THE
TELIDON TREE


First Index
or menu page
*
1. General Interest guide
2. Business guide
3. Canadian Government
4. Emergency
5. User's guide
6. Telidon explanation
7. Telephone numbers
1. General Interest Guide
Second level menu page
2. Business Guide
Second level menu page
3. Canadian Government
*
1. House of Commons
2. Senate
3. Federal reports
4. Provincial Gov't
5. Municipal Gov't
6. Canadian PM's
4. Emergency
Second level menu page
5. User's guide
Second level menu page
6. Telidon Explanation
Second level menu page
7. Telephone numler
Second level menu page
1. House of Commons
*
1. MP's
2. Liberals
3. PC's
4. NDP
5. Social credit
6. Other
2. Senate
Third level menu page
3. Federal reports
Third level menu page
4. Provincial Gov'ts
Third level menu page
5. Municipal Gov'ts
Third level menu page
6. Canadian PM's
Third level menu page
1. MP's
*
1. House standings
2. House seating plan
2. Liberals
document
3. PC's
document
4. NDP
document
5. Social credit
document
6. Other
document
1. House standings
document
2. House seating plan
document

The purpose of this study is to evaluate an experimental organization of information in the form of a tree by looking at the performance of users in finding information on Telidon. In a "good" tree, people should experience little difficulty in finding the information they want. In a "poor" tree, people will experience considerable difficulty in finding the information they want. Information organized in a tree usually refers to the organization of index terms used to access the documents (see Figure 1). The index pages or the menu pages contain lists of terms that guide the information seeker to the documents. There are many levels of index terms in the organization and they become more and more specific until they are specific enough to access the document in question. The documents are the pages that contain the information that a user is seeking. In the tree that is studied in this report there are 900 documents with 6 or fewer levels of index terms, and at each level there are 9 or fewer index terms in a menu.

The same information can be organized in a tree in many different ways. Different index terms or even different groupings of the index terms can affect the ease with which users can find information in the data base. The method described in this study can be used to evaluate any tree or hierarchical organization of information.

METHOD

Subjects

Ten participants, 6 from outside the Department of Communications and 4 from within the Department, participated in the study. None of the participants had ever seen or used Telidon before the study.

Task

At the time of this experiment, the Telidon demonstration data base contained 900 different "documents". Each document contained one kind of information. (For example, a document could contain a list of movies currently playing in Ottawa, or the latest football scores, or real estate listings, etc.) To obtain a representative sample of the kinds of information that could be found on Telidon, 16 different documents were randomly selected from the

900. The information in the document was used to phrase each question. For example, the question "Find the weather map for your present location" was designed so that people would look for the local weather report. Participants would have to make successive choices on menu pages to find the document as illustrated below. The item preceded by an asterisk is the item that should be chosen to find the document.

Example:

First menu page 1.*General Interest
2. Business Guide
3. Canadian Government
4. Emergency
5. User's Guide
6. Telidon Explanation
7. Telephone Number

Second menu page General Interest Guide
*1. News, Weather and Sports

2. Entertainment
3. Market Place
4. Employment
5. Travel
6. Advice
7. Leisure
8. Education
9. Notice Board

Third menu page News, Weather and Sports

1. News
2.*Weather
3. Sports

Fourth Menu page Weather

*1. Local
2. National
3. Special reports

Fifth menu page Local

1. Local

2. Forecast
3. Statistics
4. Temperature
*5. Map

Questions were worded very carefully so that participants were not given clues where to find the information and each request was clear enough that if the information was in the data base they would be able to find it.

Procedure

Each participant was given 16 search questions in a different random order. To find the document in question, each participant would choose items from successive menus presented on cards. Each time a participant made the wrong choice he was asked to make another choice until he chose the right item. Thus, several mistakes could be made on the same menu page. Each time a mistake was made participants were asked their reason for their choice, and the experimenter recorded all the errors and reasons for their choices. Each participant was shown a total of 79 menu pages; an average of about 5 menu pages per problem. At the end of the session participants were told the purpose of the study.

RESULTS AND DISCUSSION

The willingness of people to use Telidon will undoubtedly depend on the ease with which they can find information in the Telidon data base. To find information on Telidon, people will have to make a series of choices. Incorrect choices lead the information seeker into the wrong part of the information bank, thereby increasing search time as well as frustration. The more errors one makes, the more likely it is that one will not use Telidon.

The results of this experiment convey two kinds of information: a) information about the user, that is, about the kinds of problems that users encounter when searching for information in the tree and b) information about, the tree, that is, about the places in the tree where users experience difficulties in choosing the correct alternatives.

Overall, each person made mistakes on an average of 49.4% (or 7.9 out of 16) of the problems attempted. That is, the probability that a Telidon user will make at least one mistake on a problem is about one-half. Incorrect choices were made by one or more people on 14 of the 16 problems. The right choice was made every time on only 2 of the 16 problems.

The present experiment demonstrates people can experience considerable difficulty in finding information in a tree or hierarchically organized data base.

The 10 users made a total of 167 incorrect choices on a total of 790 menu-page presentations. Thus, each person made an average of 16.7 mistakes on 16 problems. On the average people made (16.7/16=1.04) 1.04 mistakes every time they looked for information in the data base. That is, Telidon users are likely to make at least one mistake whenever they look for information in the present 5-level information bank.

In this experiment, 80% of all errors were made on just 6 of the 79 menu pages and 53% of the errors were made on the first two levels of the tree organization. Since 53% of the errors were made on the first 2 levels and it is the pages at the first level that are accessed most often, then it would be reasonable to say that people, in general, are going to have difficulties in finding any information in this experimental data base.

Explanations given by the participants for each error committed were valuable in understanding the problems encountered in the search of information. For example, some comments were that the first page had titles that were too general and that the information should be redistributed more uniformly. At the second level they indicated that there was some overlap between some categories and some terms were judged ambiguous.

Several wrong choices were often made on the same menu page before the correct one was found. Of the 790 menu-page presentations, the correct choice was made on 679 of them and one or more wrong choices were made on 111 of the presentations. Therefore, the probability of making the right choice when a menu page is presented is 679/790= .86, and the corresponding probability that an individual will make one or more errors each time a menu page is presented is .14.

These results have implications for larger tree structures. People experienced difficulties on half of the problems when an average of only 5 menu pages was required. Commercial Telidon data bases are expected to have 15 or more levels in the tree (that is, 15 or more menu pages must be accessed sequentially). For these larger data bases, people will probably experience even greater difficulties in finding information. In a 15-level data base, for example, choices must be made on 15 different menu pages before correct information can be found. In contrast, only 5 correct decisions in a row (i.e. one correct decision per menu page) must be made to find the right information in the present Telidon data base. The probability of making the correct choice on n menu pages in a row equals the probability of making the correct choice on one menu page to the power n. Assuming that the probability with which the correct choices are made on each menu page is the same for both the 5- and a 15-level data base (i.e. P(correct choice on each menu page) = .86), then the probability that no difficulties will be experienced on a given problem

is only $(.86)^{15} = .10$.

Thus, people could experience some difficulties on over 90% of the occasions in which they search through a tree levels. This is probably a higher error rate than most people would tolerate.

Although these results point out the seriousness of the problem of finding information in a Telidon data base, they do *not* imply that people will experience serious difficulties finding information on all trees (i.e. hierarchical organizations of menu pages). In fact, the problems identified in the information bank could be solved by changing just 6 of the menu pages (over 80% of all errors occurred on just 6 pages) on the first two levels of the tree. Incorrect choices are made either because the information has been classified under the wrong heading (i.e. index term) in the menu pages, or the index term itself is ambiguous. In either case, the tree can be modified in a way that eliminates most of these incorrect choices. Further research is currently being carried out to show how information providers can detect problems in the menu pages and how to change the menu pages in a way that reduces both the number of wrong choices and the time it takes people to find information in a Telidon data base. Fewer errors and faster search times will undoubtedly increase the appeal of Telidon.